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DITCHING TESTS WITH A 1/16-SIZE DYNAMIC MODEL OF THE ARMY B-24 AIRPLANE IN LANGLEY TANK NO. 2 AND ON AN OUTDOOR CATAPULT

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MEMORANDUM REPORT

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SUMMARY

Tests were conducted to determine the best way to ditch the Army B-24 airplane in calm and rough water and to determine its probable ditching performance. A dynamically similar model of the B-24 airplane was ditched in calm water in tank no. 2 and in calm and rough water from an outdoor catapult. Its behavior was ascertained by making visual observations, by recording maximum decelerations, and by taking motion-picture records of the landings.

Conclusions based on the tests are that a water landing with a B-24 airplane should be made at as low a vertical and horizontal velocity as possible. A medium (4° or 5°) attitude ditching with flaps down appears to be slightly preferable, and if possible, the airplane should be ditched parallel to the waves. Decelerations of about 5g are to be expected. A hydroflap was found to be a very effective ditching aid for preventing dives.

Generally speaking, the tests indicate that the B-24 airplane with the extensive damage to the bottom that will probably occur in a ditching is an unsafe airplane. The model settled into the water up to the wings very soon after impact. There was a tendency to dive in certain conditions of seaway when damage caused a "nosing-in" moment.

INTRODUCTION

Object of tests.- The Army Air Forces, Air Technical Service Command, on March 26, 1943, requested that an investigation be made with scale dynamic models to determine the best way to land the Army B-24 airplane in calm and rough water and to determine its probable ditching behavior.

Place of tests.- The tests were made at Langley tank no. 2 and at an outdoor catapult.

Full-scale experience.- Reports from AAF and RAF pilots indicate that the ditchings of the B-24 are very severe. There is a great loss of life in ditchings of this airplane. In a number of instances the airplanes have broken into two or three parts when ditched. Because of a general collapse of the bottom of the fuselage, there is always a great inrush of water and the airplane sinks almost immediately to wing level.

PROCEDURE

Description of Model

A three-view drawing of the Army B-24 airplane is shown in figure 1. Two 1/16-size dynamically similar models of this airplane were used in the tests. The profile of each model was the same except for the tip of the nose. One was a model of the B-24D airplane and is shown in figure 2. The other was a model of the B-24J airplane and is shown in figure 3. A description of the type of construction of the models is given in reference 1.

The tests indicate that the ditching characteristics for the two models are similar. Therefore, for clarity in presenting the data, the test conditions and the test results are given without distinguishing one model from the other.

The B-24D model was constructed so that an extended landing gear could be installed as shown in figure 2. The extended gear was designed to fail at scale strength. The nose wheel was attached to a strut made of lead that failed in bending when a maximum aft load of 3300 pounds (full scale) was applied at the axle of the wheel. The main gear was designed to fail when a maximum aft load of 34,000 pounds (full scale) was applied at the axle of each wheel. The failure load of the main struts was set by adjusting the amount of friction in a ball and socket joint at the top of each wheel strut (fig. 4).

The B-24J model was constructed so that an extra section of fuselage, 7 feet long, full scale, could be added between the wing and the pilot's cockpit (fig. 5). The long fuselage was essentially similar to that used on the Navy PB4Y-2 airplane.

Test Methods and Equipment

The apparatus and test procedure used are described in reference 1.

Test Conditions

(All values given refer to the full-scale airplane.)

Gross weight.- The model was tested at gross weights from 43,000 pounds to 56,500 pounds.

Location of center of gravity.- The horizontal location of the center of gravity was 29.5 percent of the mean aerodynamic chord except for a few tests which were made with the center of gravity at 24 percent and 32 percent of the mean aerodynamic chord. The vertical location was 7.84 inches below the thrust line of the inboard nacelles.

Attitude of the thrust line at contact.- The attitudes of the thrust line at contact with the water were 9°, 7.5°, 6°, 5°, and 1°.

Flap setting.- Tests were made with flaps up and with flaps down 40°.

Landing speed.- The speeds used for all conditions were computed from information obtained from the Consolidated Vultee Aircraft Corporation.

The airspeeds used at the outdoor catapult were scale airspeeds for a flaps-down landing made with no power.

The winds were frequently gusty so that some of the runs were made with indicated airspeeds inadvertently higher or lower than the scale speeds. A few of those runs in which the model stayed in trim and appeared to make a normal landing with no excess vertical velocity are presented.

The speeds used in tank no. 2 covered a range of ground speeds for each attitude tested. These speeds bracketed the scale airspeeds and, therefore, the model was not necessarily airborne at each test speed. This was done to investigate any hydrodynamic variation with ground speed that might exist.

Simulated damage.- The possible damage sustained by the full-scale airplane in a ditching was simulated by removing the corresponding parts from the model. In a few tests made on the outdoor catapult, the openings cut in the model were covered with thin paper. This thin paper simulated a weak door or window but was not to scale strength. The conditions of simulated damage that were tested are described by listing the parts of the model that were removed (cut out) and are as follows:

(a) No damage. Figure 3.

(b) Nose window, nose-wheel doors, bomb-bay doors, belly turret, and bottom rear entrance door removed. Figure 6.

(1) No bulkhead just aft of bomb bays.

(2) Partial bulkhead just aft of bomb bays. Figure 7.

(c) Bomb-bay doors removed.

(1) No bulkhead just aft of bomb bays.

(2) Partial bulkhead just aft of bomb bays.

(3) Solid bulkhead just aft of bomb bays.

(d) Nose window, nose-wheel doors, belly turret, and bottom rear entrance door removed.

(e) Nose window and nose-wheel doors covered with paper, bomb-bay doors partially closed, solid bulkhead just aft of bomb bays.

(f) Nose window and nose-wheel doors covered with paper, bomb-bay doors removed, solid bulkhead just aft of bomb bays.

Ditching aids.- During part of the tests, several devices were added to the model to improve its ditching characteristics. Various sizes, shapes, and angles of incidence were tested for each of these ditching aids. The type of ditching aids that were tested are as follows:

(a) Hydroflap attached near the nose-wheel doors to hold the nose out of the water. Figure 8.

(b) Hydrospoiler attached near the nose-wheel doors to destroy any suction under the nose. Figure 9.

(c) Devices attached near the tail to hold the tail in the water (water scoop and hydrofoil). Figures 10 and 11.

Fuselage length.- A few tests were made with a section (7 feet long, full scale) added to the fuselage between the wing and the pilot's cockpit. The long fuselage (fig. 5) approximated that used on the Navy PB4Y-2 airplane.

Landing gear.- The majority of the tests were made with the wheels retracted but a few tests were made with the wheels extended.

Seaway.-

(a) Calm water.

(b) Wave crest parallel to the flight path, height 2 to 7 feet.

(c) Wave crests perpendicular to the flight path, height 2 to 7 feet.

PRESENTATION OF RESULTS

Landing speeds for the B-24 airplane are shown in table I.

Data from tank tests with the model in different conditions of damage and covering a range of ground speeds for various landing conditions are presented in table II.

Those data from tank tests with the model operated at scale airspeeds for power-off, flaps-down landings are offered in table III.

Ditching performance of the model in open seaway at the outdoor catapult is summarized in table IV.

Photographic sequences of typical ditchings of the model are presented in figures 12 through 17.

Time-history records of longitudinal deceleration are shown in figures 18 and 19.

The results presented in this report agree closely with those reported for tests made with models of the B-24 airplane at the Royal Aircraft Establishment, Farnborough, England. The RAE tests were also made on both calm and rough water. (See references 2 and 3.)

DISCUSSION

Because of the very weak bomb-bay doors (safe load of less than 178 pounds per square foot) and general weakness of the bottom of the fuselage, it is likely that the airplane will be completely flooded immediately after it contacts the water. If the bomb-bay doors fail completely, a dive probably will result. A "dive" is interpreted to mean any performance in which the nose of the airplane is forced to enter the water while the airplane is traveling at appreciable speed. Most of the airplane may be under water in a near level attitude or in extreme cases the attitude may be appreciably negative to the horizontal. In this event the fuselage will be flooded and also high decelerations possibly will result. The model tests indicated that these ditching characteristics could be improved by the use of ditching aids.

<u>Effect of attitude and speed</u>.- In smooth-water tank tests, <u>high-attitude ditchings of</u> the model with the bomb-bay doors removed generally resulted in diving. Low-attitude ditchings of the model usually resulted in skipping or porpoising although occasional dives occurred.

Changes in groundspeed did not greatly affect the hydrodynamic behavior of the model.

The highest maximum longitudinal decelerations of about 5g were recorded at the 9° attitude and the lowest of about 2g were recorded at the 5° and 1° attitudes.

In general, the decelerations and the diving tendencies in smooth water tended to decrease with decreasing attitudes. However, it is doubtful that any advantage would be gained by a very low-attitude ditching because of the probability of increased damage due to greater dynamic pressures at the higher speeds of the low-attitude ditching.

<u>Effect of flap setting</u>.- The flaps had no appreciable effect on the hydrodynamic performance of the model. Therefore a ditching should be made with flaps down in order to take advantage of the lower horizontal velocity thus afforded.

<u>Effect of vertical velocity</u>.- The performance of the model was impaired with an increase in the vertical velocity. See table II, parts E and F.

<u>Effect of location of center of gravity</u>.- When the center of gravity was located either at 24 or 32 percent mean aerodynamic chord the performance was essentially the same as in part G of table II and so is not listed separately.

<u>Effect of simulated damage</u>.- When the model was ditched with no damage simulated, it made smooth runs or skipped or porpoised with maximum decelerations usually between 1g and $3\frac{1}{2}$g. However, it is not likely that the airplane will be strengthened enough to prevent extensive damage of the bottom of the fuselage in a ditching. When ditchings were made with damage simulated, the model usually settled into the water up to the wings very soon after impact.

In the tests when the bomb-bay doors were removed the inrushing water apperently produced a nosing-in moment which frequently caused a dive. Maximum deceleration of 3g to 5g resulted. This was especially true in the high-attitude landings.

When other doors in addition to the bomb-bay doors were removed, there was not a substantial change in the ditching performance of the model. In the tests where the nose window and the nose-wheel doors were covered with thin paper, the paper always failed on contact with the water.

In tests made with the bomb-bay doors partially closed the nosing-in moment was reduced and the ditching performance appeared to be better than with the doors removed. However, the performance was not as good as with the doors completely closed.

Effect of ditching aids.- Selected results from each type of ditching aid tested are given in table II. A trapezoidal hydroflap attached at the after edge of the nose-wheel door was more effective in preventing diving than the other types of aids tested. It is also believed to be the aid most easily applicable to the full-scale airplane. Various other trapezoidal, rectangular, and square hydroflaps were tested, but the one shown in figure 8 gave the smoothest runs.

Hydrospoilers (fig. 9) also prevented diving but the behavior of the model was not as smooth as when a hydroflap was used.

Water scoops and hydrofoils (figs. 10 and 11) were attached near the tail in an effort to hold the tail in the water. The performance with these devices was inconsistent. On some runs they prevented diving but on other runs at similar conditions very violent dives occurred. The smallest hydrofoil that always prevented diving in the model tests is shown in figure 11(b). However, it is believed that the size of this hydrofoil and the structure necessary to support it are so great that it would be impractical to install on the B-24 airplane.

Effect of fuselage length.- Increasing the length of the fuselage (fig. 5) improved the ditching characteristics somewhat but did not entirely eliminate diving (table II).

Effect of landing gear.- The model dived during almost every ditching made with nose wheel, main wheels, or all three wheels down (table II).

Effect of load.- There was no pronounced change in hydrodynamic performance between ditchings at heavy and light load conditions.

Effect of seaway.- A wide range of wave heights was encountered in the rough-water tests. When ditched directly across the waves, the model frequently dived deeply into an oncoming wave. The ditchings were improved when the contact with the water was made just after the crest of the wave had passed. A few runs were made into a head wind of 30 to 50 miles per hour (full scale). In these landings the airplane nosed into a wave in a few cases but the ground speed was reduced enough so that the impact appeared to be "soft." Landings made in the trough of the wave and parallel to the wave crest were generally better than those made across the waves.

CONCLUSIONS

The following conclusions are based on model tests:

1. The airplane should be ditched in a medium (4° or 5°) attitude with flaps down.

2. The ditching should be made with as low a vertical and horizontal velocity as possible.

3. The airplane should be ditched parallel to the waves if feasible, but if a ditching is made into the wind and across the waves, an attempt should be made to contact just after the crest of the wave had passed.

4. Crew members should brace themselves in a ditching to withstand longitudinal decelerations of 5g and should prepare to immediately abandon the airplane which will quickly be flooded with water.

5. Certain ditching aids will improve the ditching performance of the airplane. A hydroflap was the most effective of all the ditching aids tested in preventing dives.

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REFERENCES

1. Fisher, Lloyd J., and Steiner, Margaret F.: Ditching Tests with a 1/12-Size Model of the Army B-26 Airplane in NACA Tank No. 2 and on an Outdoor Catapult. NACA MR, Aug. 15, 1944.

2. MacPhail, D. C., and Ross, J. G.: Model Tests of the Alighting of Landplanes on the Sea. Part 3. Liberator. Rep. No. Aero 1770, British R.A.E., Aug. 1942.

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TABLE I - LANDING SPEEDS

Flaps down, power off

Weight (lb)	Attitude thrust line (deg)	Airspeed (mph)
43,000	9	86
48,500	9	92
56,500	9	99
43,000	5	97
48,500	5	101
56,500	5	109
43,000	1	115
48,500	1	123
56,500	1	133

Note: These speeds were determined from data obtained from Consolidated Vultee Aircraft Corp.

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TABLE II - DITCHING PERFORMANCE OF A 1/16-SIZE MODEL OF AN ARMY B-24 AIRPLANE LANDED ON CALM WATER IN LANGLEY TANK NO. 2

[All values are full-scale except where qualified; gross weight, 48,500 to 56,500 pounds.]

	Attitude of thrust line at contact		9°												5°						1°		
	Groundspeed (mph)		80			100			110			120			100			120			120		
	Structural condition of model	See Note	Max. Dec.	Run	Rmk.	Max. Dec.	Run	Rmk.	Max. Dec.	Run	Rmk.	Max. Dec.	Run	Rmk.	Max. Dec.	Run	Rmk.	Max. Dec.	Run	Rmk.	Max. Dec.	Run	Rmk.
A	No damage simulated.	Flaps up				3.0 2.9 2.7	5 4 4					3.3 3.0 3.0	5 5 6					1.2 0.9	14 12	s p			
		Flaps down 40°	2.8 2.8	2 4		3.7 3.7	4 4 9 8	p p							1.8 1.2 1.4	9 8 9	p p				1.4 3.5 1.4	8 17 10 9	s s
B	Bomb-bay doors removed. No bulkhead aft of bomb bays.	Flaps down 40°	5.9 5.3 5.7	1 1 1	d	4.9 4.4 4.0	2 1	d d d							3.0 3.0 3.1	4 4 4					1.8 2.1	9 8	s s
C	Bomb-bay doors removed. Solid bulkhead just aft of bomb bays.	Flaps down 40°	5.6 5.4	1 2	d d	5.3 5.0	1 1	d d							3.2	3	d						
D	Bomb-bay doors removed. Partial bulkhead just aft of bomb bays.	Flaps down 40°	4.0	1 1	d d	4.4 5.0 4.8	1 1 1 2 2	d d d d d		1 3	d d					3 5 7 6	d p p p				5.2 2.6	3 5 7 3 2	d d d
E	Nose window, nose-wheel doors, bomb-bay doors, belly turret, bottom rear entrance door removed. No bulkhead aft of bomb bays.	Flaps down 40°	3.1 2.9	2 2		3.1 3.0	3 4								2.3 2.3	5 5	p p				2.0 1.9	9 9	s s
F	Same as part "E" above except that model is launched from 4 in. above the water instead of 1 in. above so as to increase the vertical velocity.	Flaps down 40°	4.2 3.7	1 1	d d	4.1 3.6	1 3	d s							2.0 2.6	4 4					3.3 1.5 1.2	4 5 4	d t t
G	Nose window, nose-wheel doors, bomb-bay doors, belly turret, bottom rear entrance door removed. Partial bulkhead just aft of bomb bays.	Flaps down 40°					2 3 2	d d d		2 5 2	d d d					4 3 4	pd pd pd					4 5 11 3	s s sp d
H	Nose window, nose-wheel doors, belly turret hole, bottom rear entrance door removed.	Flaps down 40°	1.1 1.0	4 5		1.0 1.5 1.0	6 4 5 7	p p													1.2 2.2	8 7 4 9	s s p
J	7-foot section of fuselage added between wing and pilot's cockpit. Damage as in part "D" above.	Flaps down 40°					3 2	d		3 7 1 5	d d											15 14	s s

Note:
Max. Dec. - Maximum deceleration in multiples of the acceleration of gravity.
Run - Length of run in multiples of the length of the airplane.
Rmk. - Remarks (see Symbols).

Symbols:
d - dived.
p - porpoised (oscillated in trim).
s - skipped (left the water).
t - turned sharply.

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TABLE II - CONCLUDED.

[All values are full-scale except where qualified; gross weight, 48,500 to 56,500 pounds.]

	Attitude of thrust line at contact		9°				7-1/2°				6°				1°			
	Groundspeed (mph)		100		110		100		110		100		110		110		120	
	Structural condition of model	See Note	Run	Rmk.	Run	Rmk.	Run	Rmk.	Run	Rmk.	Run	Rmk.	Run	Rmk.	Run	Rmk.	Run	Rmk.
K	7-foot section of fuselage added between wing and pilot's cockpit. Damage as in part "G".	Flaps down 40°	4	d	3 10 6	d p p											13 11	s s
L	Trapezoidal hydroflap attached at after edge of nose-wheel doors. See fig. 8. Damage as in part "G".		5 5 6	p p p	6 6 6 6	p sp p sp					4 5	p p	5 5	p p	6 6	p p	7	p
M	Trapezoidal hydroflap attached at after edge of nose-wheel doors. See fig. 8. Damage as in part "A".										7 7	p p	8 10	sp sp				
N	Triangular hydrospoiler attached at after edge of nose-wheel doors. See fig. 9. Damage as in part "G".		3	p	3 4	p p												
P	Water scoop attached over opened rear entrance door. See fig. 10. Damage as in part "D".		2 3 2	d d d	3 4 2 2	d p d d									3 3	d d	11 9	sp sp
R	Hydrofoil attached under tail. See fig. 11(a). Damage as in part "D".		6 5 3	p p d	3 3 2 4	td td d d	5 4 5	p d p	4 3 2	d d d					3 6 6	d p p		
S	Damage as in part "D". 3 wheels down.		2 2 1	d d d													4 3 5 4	st sd sd t
T	Damage as in part "D". Main wheels down only.																2 2 2	td td d
U	Damage as in part "D". Nose wheels down only.		3 5 2	sd sd sd													6 6 6	sd st sd
V	Damage as in part "A". 3 wheels down.		3 2 3 3	t d t d													2 2 3	sd sd sd

Note:
Max. Dec. - Maximum deceleration in multiples of the acceleration of gravity.
Run - Length of run in multiples of the length of the airplane.
Rmk. - Remarks (see Symbols)

Symbols:
d - dived.
p - porpoised (oscillated in trim).
s - skipped (left the water).
t - turned sharply.

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TABLE III - DITCHING PERFORMANCE OF A 1/16-SIZE MODEL OF AN ARMY B-24 AIRPLANE LANDED AT SCALE AIRSPEEDS ON CALM WATER IN LANGLEY TANK NO. 2

[Flaps down 40°.
All values are full-scale.]

Structural condition of model	Attitude thrust line (deg)	Computed airspeed (mph)	Test speed (mph)	Maximum deceleration (g)	Performance in water
No damage simulated.	9	92	92		Smooth run.
	1	122	120	1.4 - 3.5	Trimmed up, skipped.
Bomb-bay doors removed. No bulkhead aft of bomb bays.	9	92	90	4.0	Dived.
	5	103	100	2.7	Smooth run. Ran low in water.
	1	122	120	1.8	Skipped.
				2.1	Smooth run.
Nose window, nose-wheel doors, bomb-bay doors, belly turret, bottom rear entrance door removed. Partial bulkhead just aft of bomb bays.	9	92	90	3.8 - 4.5	Tended to dive, or dived.
				3.0 - 2.9	Trimmed up, smooth run.
				3.7	Smooth run.
	5	103	100	2.3	Porpoised.
				1.7	Smooth run.
	1	122	120	3.3	Dived.
				1.0 - 4.0	Porpoised.
Nose window, nose-wheel doors, bomb-bay doors, belly turret, bottom rear entrance door removed. Solid bulkhead just aft of bomb bays.	9	92	90	3.6	Stopped quickly.
				2.1	Nose and nacelles dug in.
	5	103	100	4.0	Stopped quickly.
				3.7	Nose and nacelles dug in.

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TABLE IV - DITCHING PERFORMANCE OF A 1/16-SIZE MODEL OF AN ARMY B-24 AIRPLANE LANDED IN VARIOUS CONDITIONS OF SEAWAY AT AN OUTDOOR CATAPULT

Smooth Water

[Flaps down, 40°
All values are full scale]

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Attitude thrust line (deg)	Scaled airspeeds (mph)	Measured airspeeds (mph)	Ground speeds (mph)	Condition of damage	Performance in water
9	92	91	79	A	Nacelles dug in, then model porpoised slightly, and dived slightly at end of short run.
9	92	97	120	A	Settled in quickly with nose burying and causing short run.
9	86	88	88	B	Shallow dive.
9	86	88	88	B	Porpoised slightly, nacelles and nose dug in at end of run.
9	92	92		C	Trimmed up, nose clear until late in run.
9	90	92		D	Trimmed up, nacelles and nose dug in late in run.
5	103	100	88	A	Smooth run, nose clear during most of run.
5	105	105	93	A	Porpoised slightly, fuselage low in water up to wings.
5	103	105	93	A	Wing low, straightened on contact, fuselage run low in water.
5	98	105	105	B	Pitched up and down, nose dug in at end of run.
5	98	108	80	B	Shallow dive.
5	105	106		C	Trimmed up, nose clear until late in run.
5	98	100		D	Trimmed up, smooth run until nose and nacelles dug in.
1	122	122	122	A	Most of nose clear until nacelles dug in slightly at end of run.
1	115	120	120	B	Porpoised with fuselage low in water.
1	120	124	134	B	Pitched up and down until nose dug in slightly at end of run.
1	120	124	134	B	Pitched up and down until nose dug in slightly at end of run.
1	122	120		C	Pitched up and down or skipped, nose clear.
1	122	125		D	Trimmed up then porpoised.

A - Nose window, nose-wheel doors, bomb-bay doors, belly turret, rear entrance hatch removed, partial bulkhead just aft of bomb bays.
B - Nose window and nose-wheel doors covered with thin paper, bomb-bay doors removed, solid bulkhead just aft of bomb bays.
C - Complete model, simulating no damage to full-scale airplane.
D - Nose window and nose-wheel doors covered with thin paper, bomb-bay doors partially closed, solid bulkhead just aft of bomb bays.

TABLE IV - Continued.

Ditchings Along Waves, Across Wind

[Flaps down, 40°
All values are full scale]

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Wave height (ft)	Attitude thrust line (deg)	Scaled airspeeds (mph)	Measured airspeeds (mph)	Ground speeds (mph)	Condition of damage	Performance in water
2	9	92	92	92	B	Nacelles dug in deeply in rough water, tended to dive.
4	9	92	92	92	B	Nacelles dug in deeply in rough water, tended to dive.
2	9	96	102	102	A	Tended to dive, high spray raised.
5	9	86	96	96	B	Porpoised with nacelles digging in at end of run.
6	9	86	88	70	B	Dived through wave.
4	9	86	92	62	B	Tended to dive as nose and nacelles buried in water.
5	9	94	97		D	Trimmed up then rotated forward and tended to dive.
6	5	103	105	90	B	Shallow dive into quartering waves.
3	5	107	105	100	A	Nose and nacelles dug in deeply in waves.
5	5	107	107	107	B	Smooth run.
4	5	97	107	107	B	Dived into wave.
4	5	100	102		D	Pitched up and down, nose dug in deeply at end of fairly long run.
6	1	115	120	110	B	Trimmed up then settled in at end of run.
3	1	115	117	117	B	Settled quickly up to wings with little spray.
4	1	116	118		D	Trimmed up until late in run when it settled in.

A - Nose window, nose-wheel doors, bomb-bay doors, belly turret, rear entrance hatch removed, partial bulkhead just aft of bomb bays.
B - Nose window and nose-wheel doors covered with thin paper, bomb-bay doors removed, solid bulkhead just aft of bomb bays.
D - Nose window and nose-wheel doors covered with thin paper, bomb-bay doors partially closed, solid bulkhead just aft of bomb bays.

TABLE IV - Concluded.

Ditchings Across Waves, Into Wind

[Flaps down, 40°
All values are full scale]

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Wave height (ft)	Attitude thrust line (deg)	Scaled airspeeds (mph)	Measured airspeeds (mph)	Ground speeds (mph)	Condition of damage	Performance in water
3	9	92	97	75	A	Wing slightly low. Turned in a dive.
3	9	92	96	68	A	Rode over waves with nose clear until end of run.
4	9	92	95	67	A	Dived into a wave.
5	9	86	88	48	B	Tail contacted before a crest, nose ploughed through next wave.
5	9	85	85	55	B	Ploughed through a high wave.
4	9	86	86		D	Rode over waves in several runs. In remaining runs, the tail was thrown upward and the model dived into a wave.
2	5	107	105	65	A	Rode over waves.
4	5	107	104	76	A	Dived into a wave.
3	5	107	104	76	A	Rode over waves.
5	5	98	102	92	B	Rode over waves. Nacelles dug in at end of run.
7	5	100	104		D	Porpoised, nose dug in slightly in waves.
3	1	125	121	101	A	Pitched up and down.
3	1	125	120	93	A	Shallow dive.
3	1	125	122	85	A	Rode over waves with nacelles raising slight spray.
8	1	115	120	75	B	Rode over waves with nacelles raising slight spray.
7	1	117	120		D	Rode over waves in most runs.

A - Nose window, nose-wheel doors, bomb-bay doors, belly turret, rear entrance hatch removed, partial bulkhead just aft of bomb bays.
B - Nose window and nose-wheel doors covered with thin paper, bomb-bay doors removed, solid bulkhead just aft of bomb bays.
D - Nose window and nose-wheel doors covered with thin paper, bomb-bay doors partially closed, solid bulkhead just aft of bomb bays.

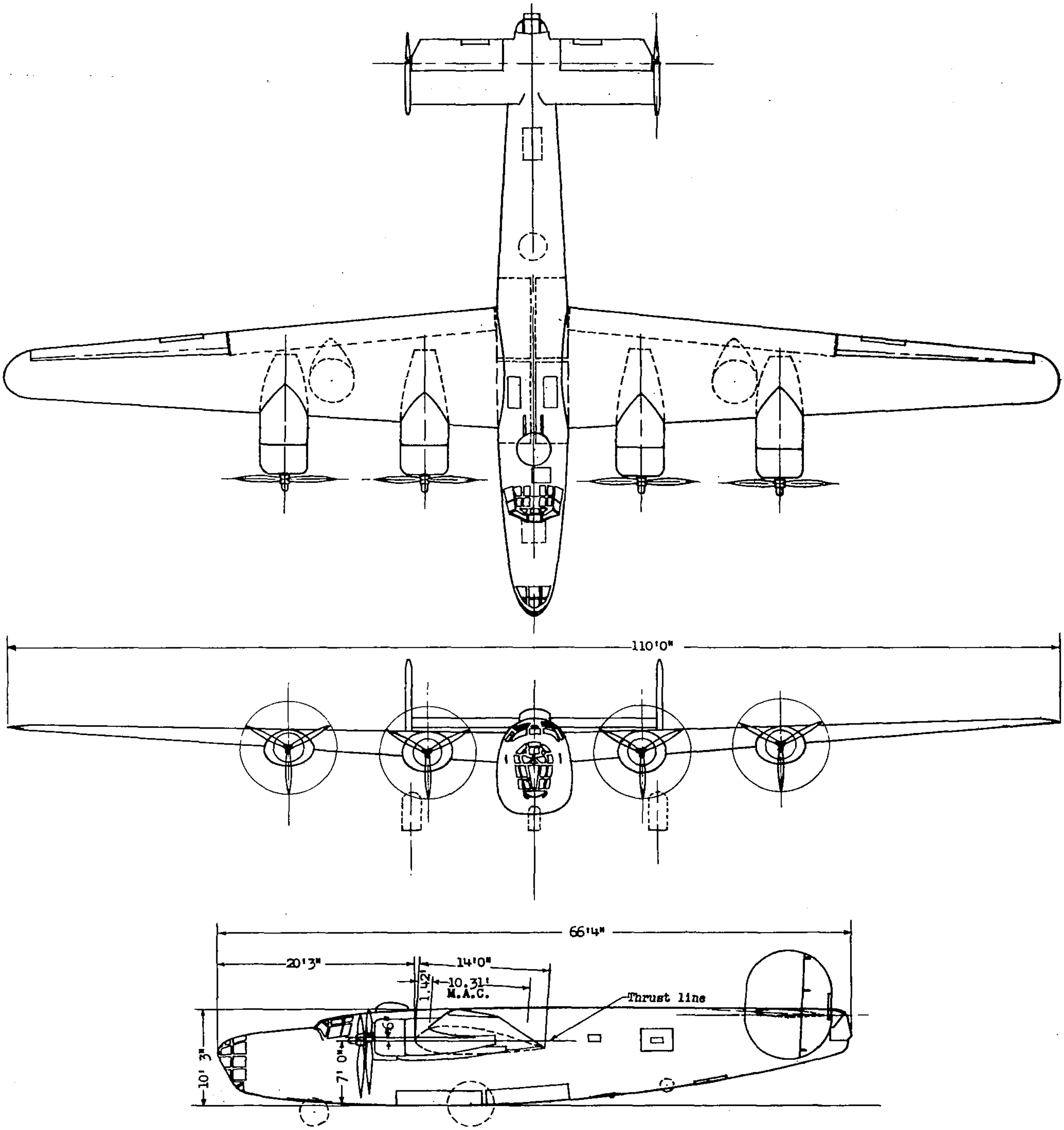

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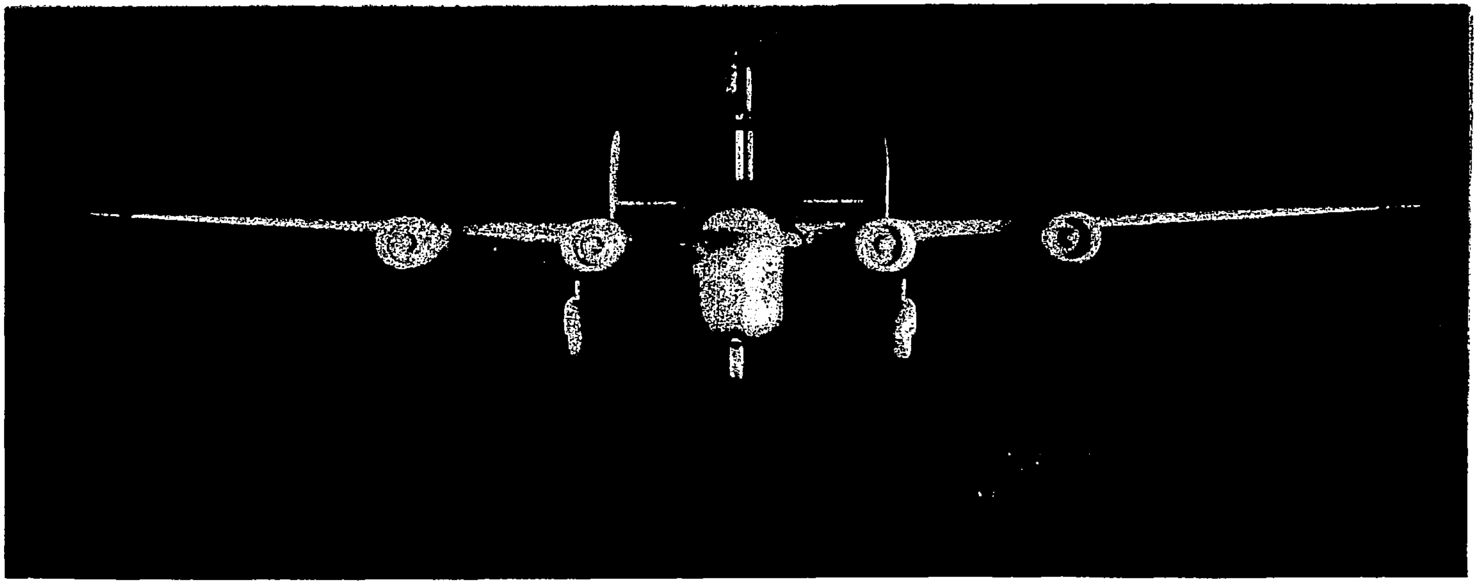
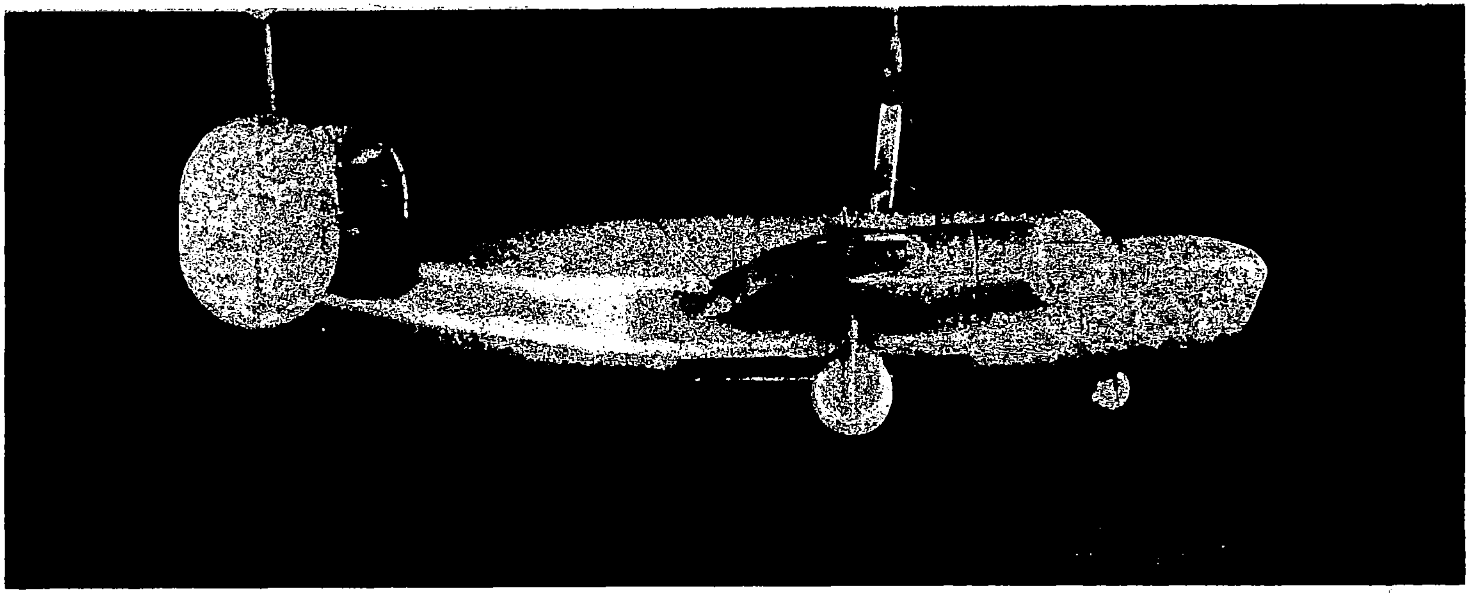
Figure 1.- Three-view drawing of the Army B-24 airplane.



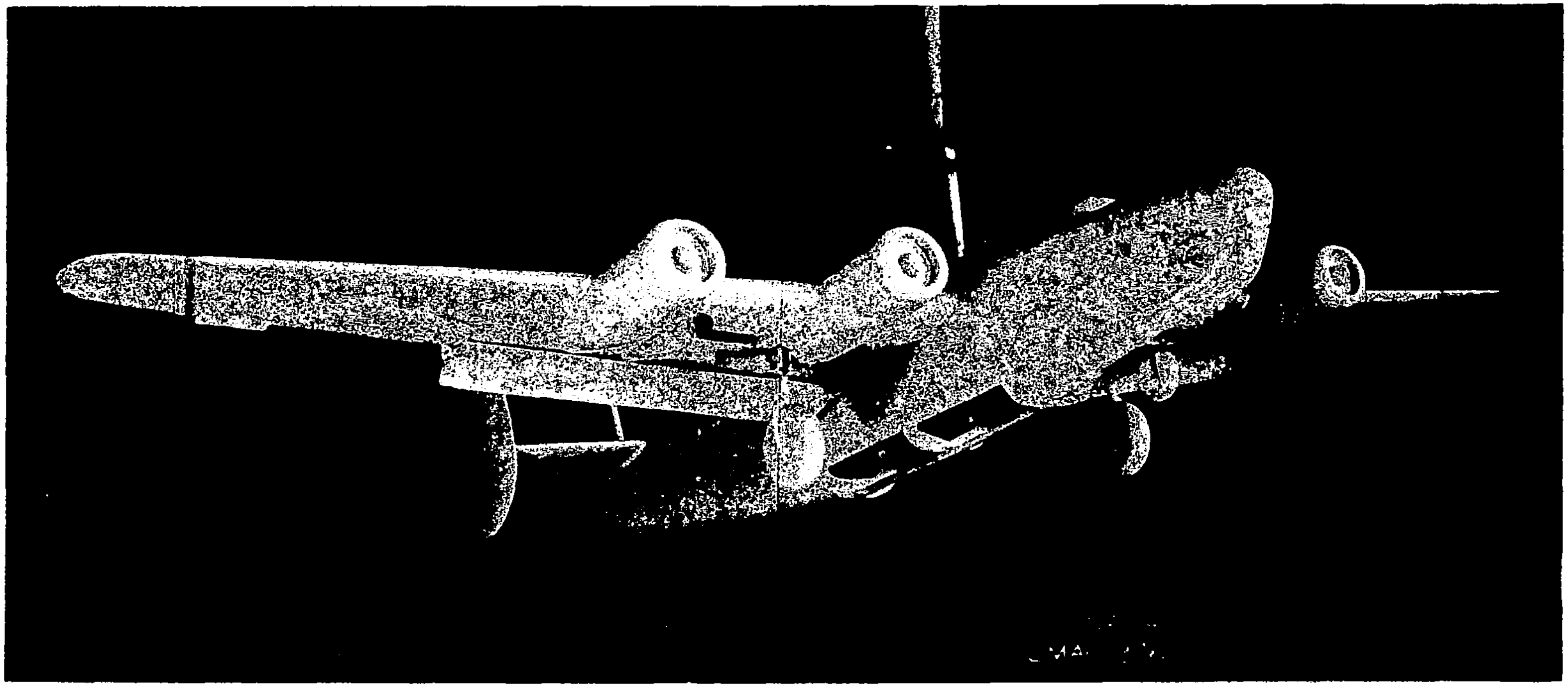
(a) Front view.

Figure 2.- Photograph of a $\frac{1}{16}$-size model of an Army B-24D airplane with scale strength landing gear in the down position.



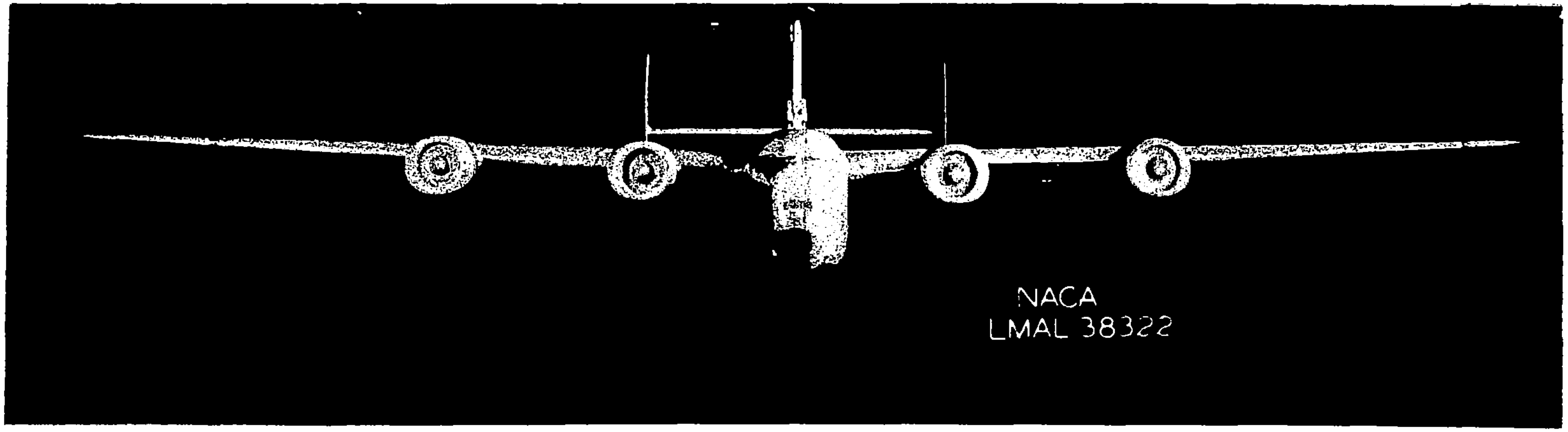
(b) Side view. The nose wheel is notched so that it can fall back partially into the open wheel compartment.

Figure 2.- Continued.



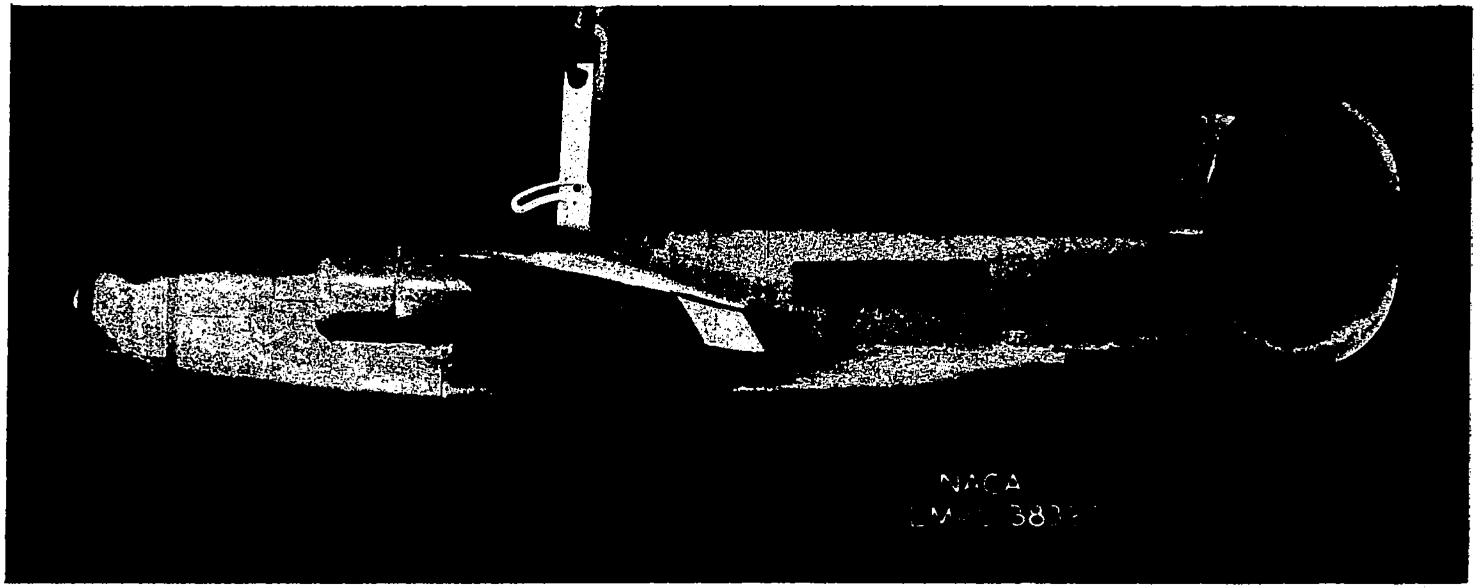
(c) Front three-quarter bottom view.

Figure 2.- Concluded.



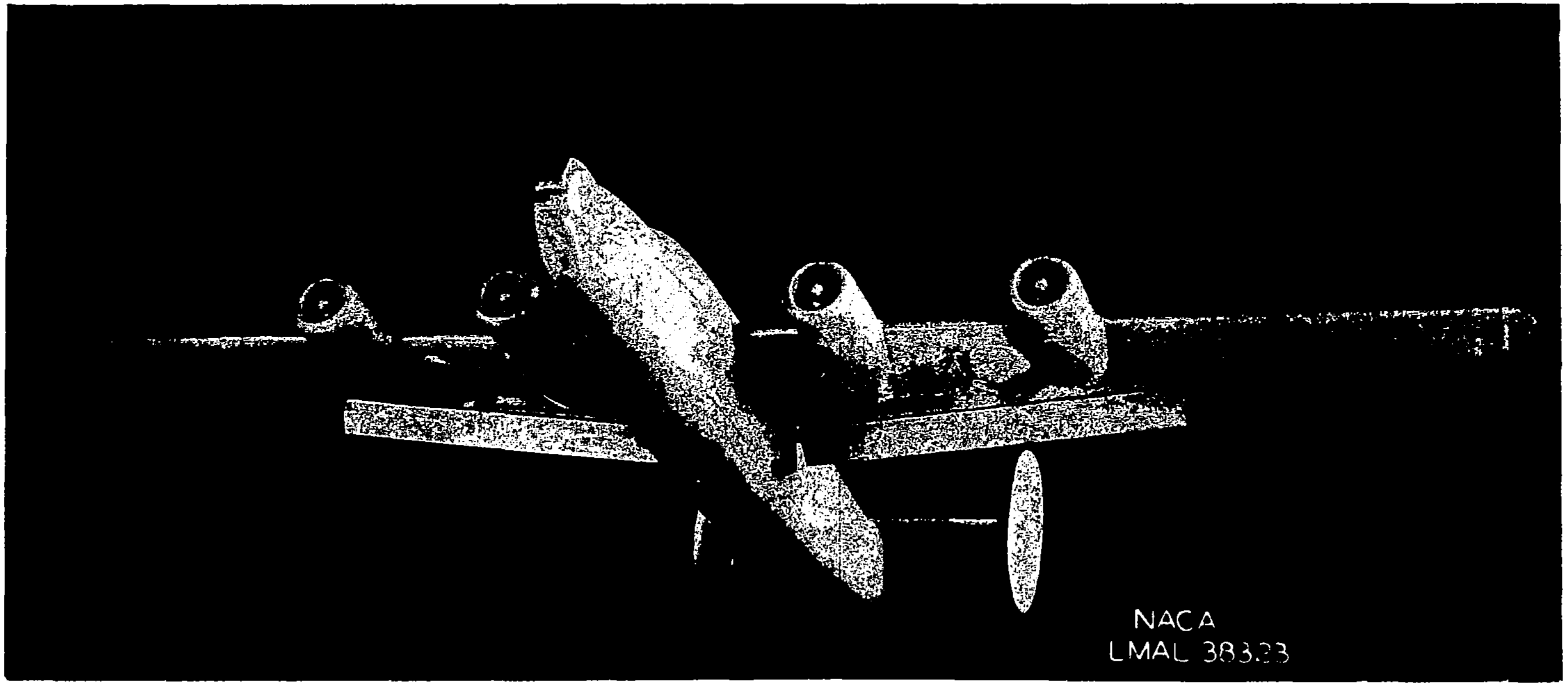
(a) Front view.

Figure 3.- Photograph of a $\frac{1}{16}$-size model of an Army B-24J airplane.



(b) Side view.

Figure 3.- Continued.



(c) Front three-quarter bottom view.

Figure 3.- Concluded.

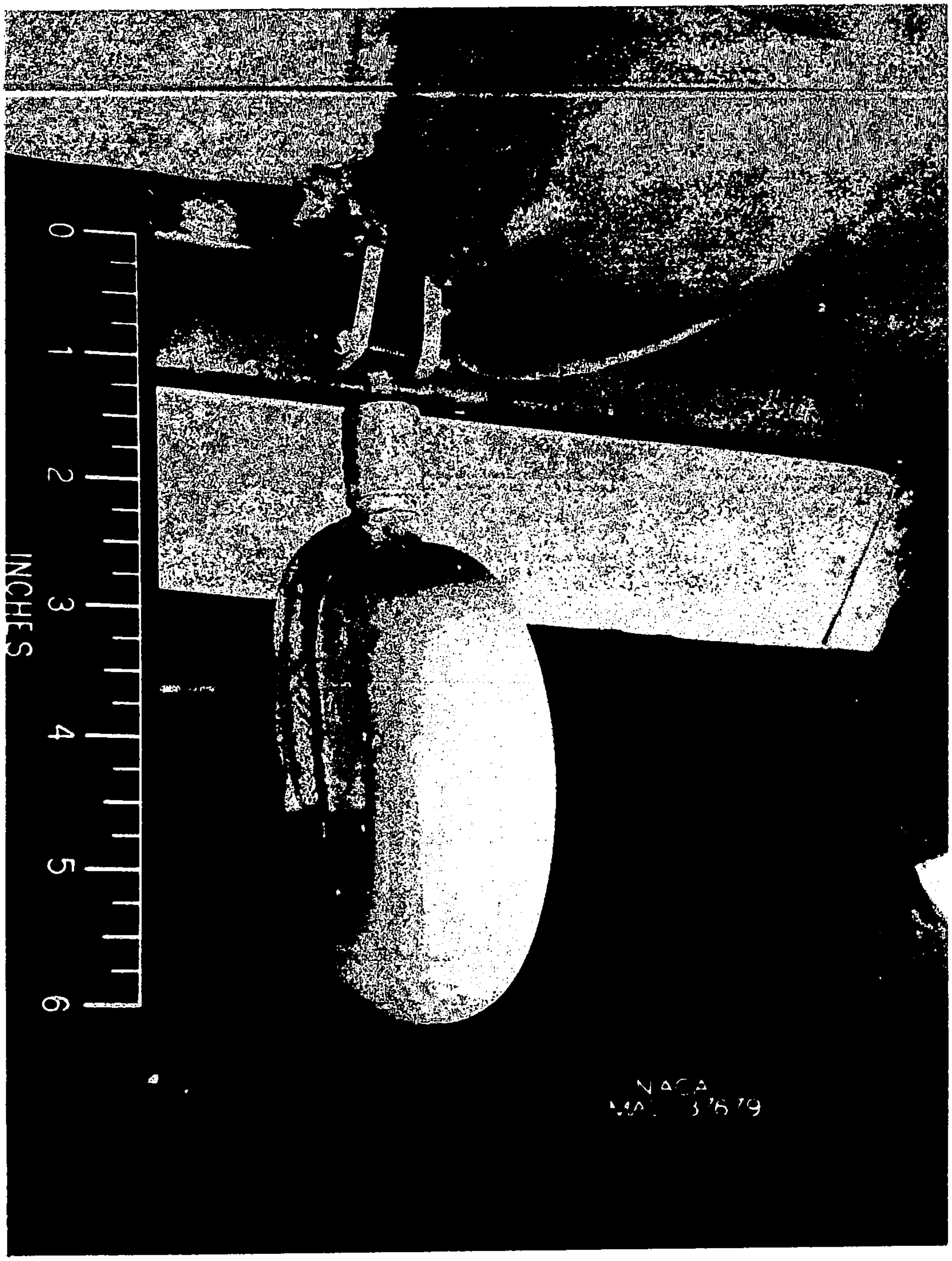


Figure 4.- Photograph of the right main landing wheel on a $\frac{1}{16}$-size model of an Army B-24 airplane showing ball and socket joint used in making scale strength adjustments.

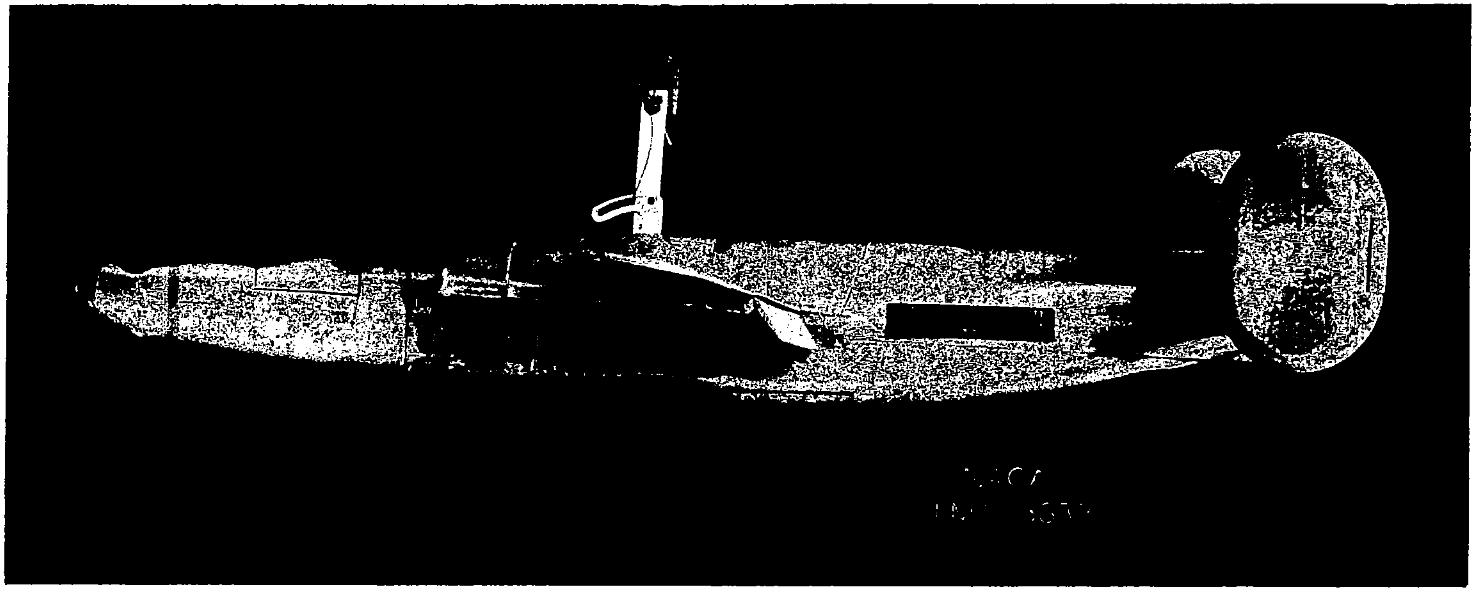


Figure 5.- Photograph of a $\frac{1}{16}$-size model of an Army B-24 airplane showing an extra section of fuselage (7 feet, full scale) added just forward of the wing.

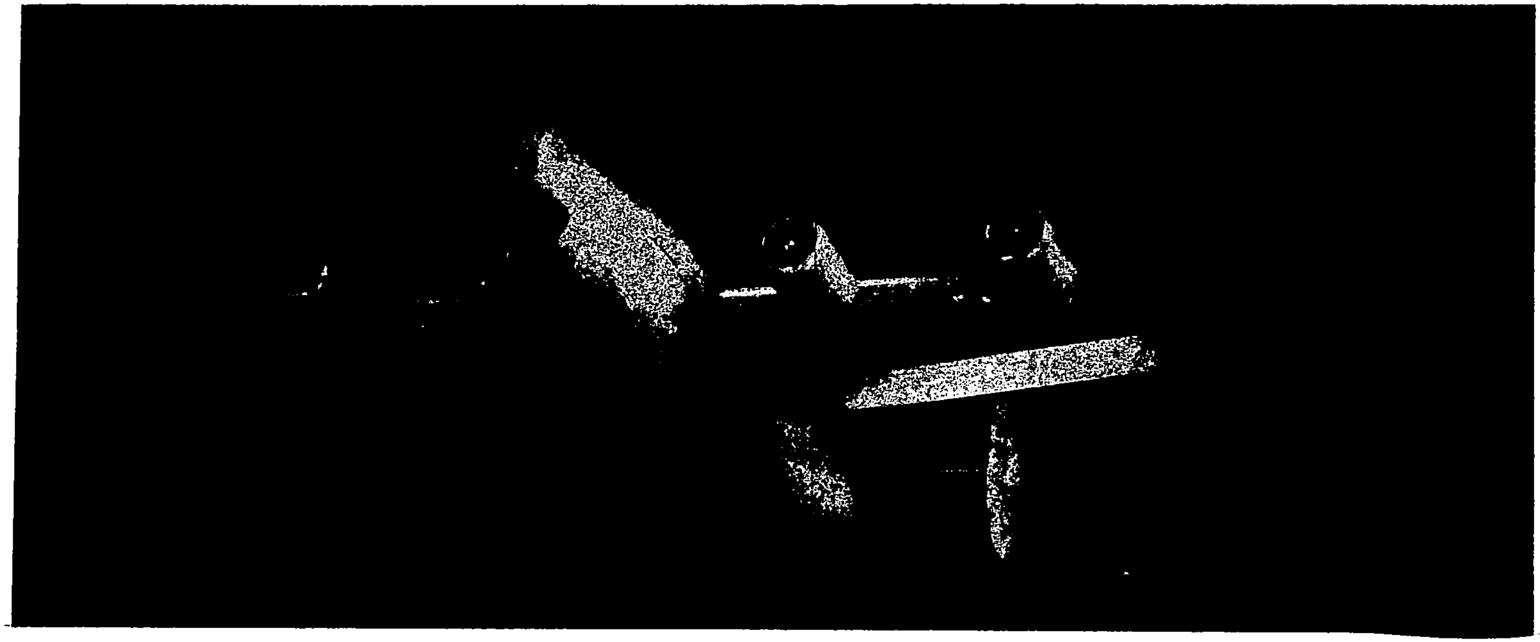


Figure 6.- Photograph of a $\frac{1}{16}$-size model of an Army B-24 airplane showing openings cut to simulate failure of nose window, nose-wheel doors, bomb-bay doors, belly turret, and bottom rear entrance hatch.

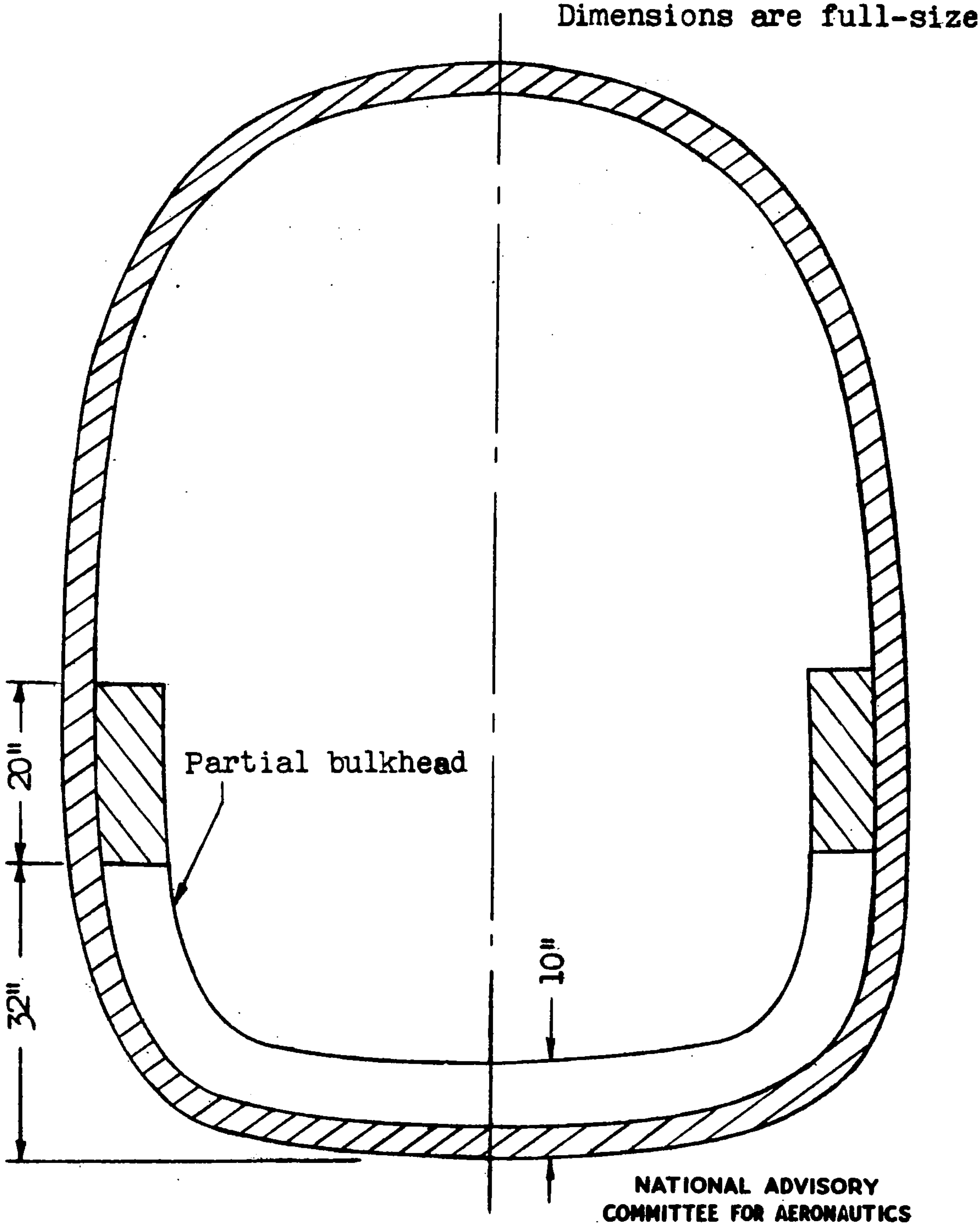


Figure 7.- Drawing showing partial bulkhead in fuselage just aft of bomb-bays on a model of an Army B-24 airplane.

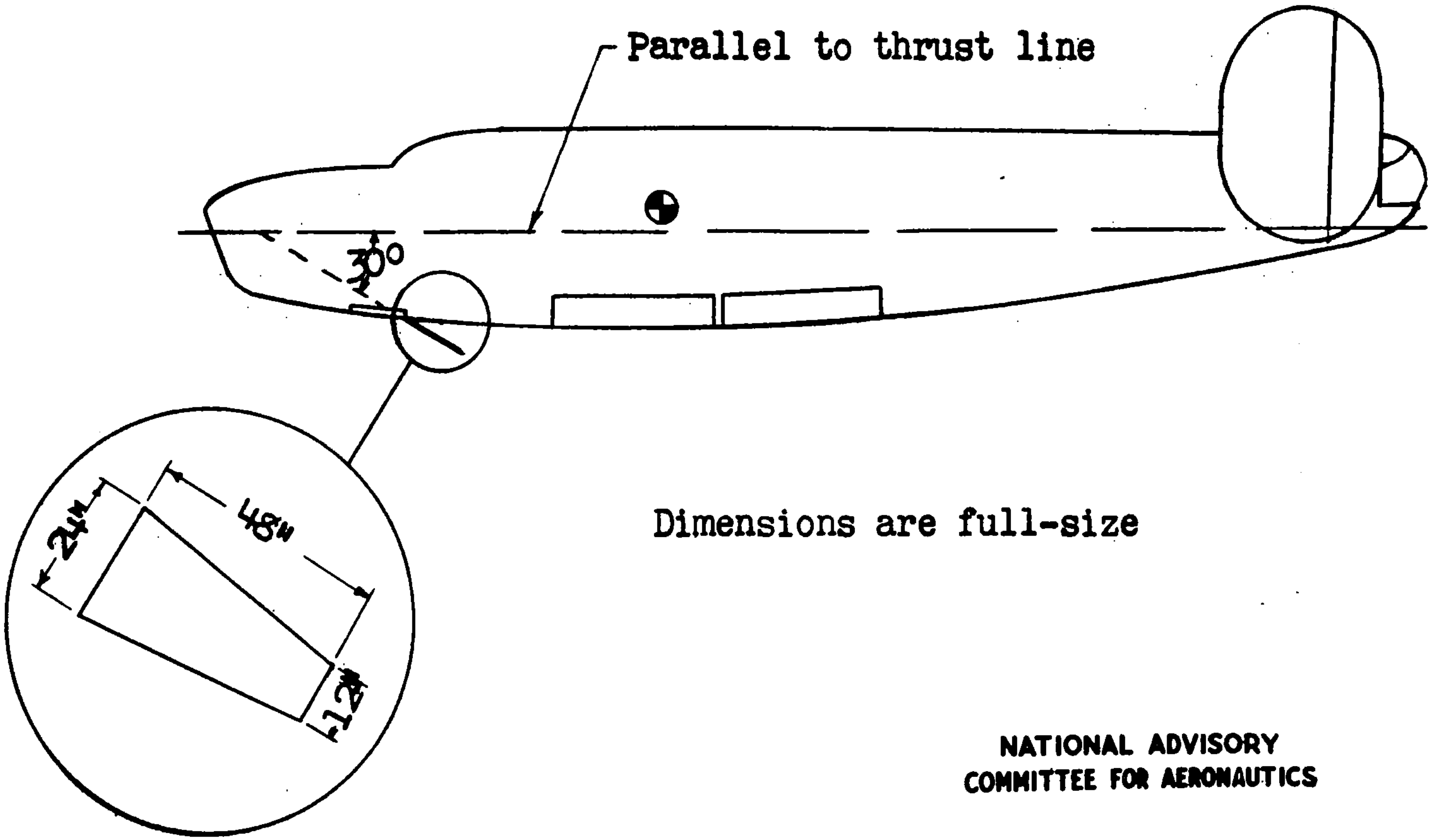


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Figure 8.- Drawing showing a trapezoidal hydroflap and its location on a model of an Army B-24 airplane.

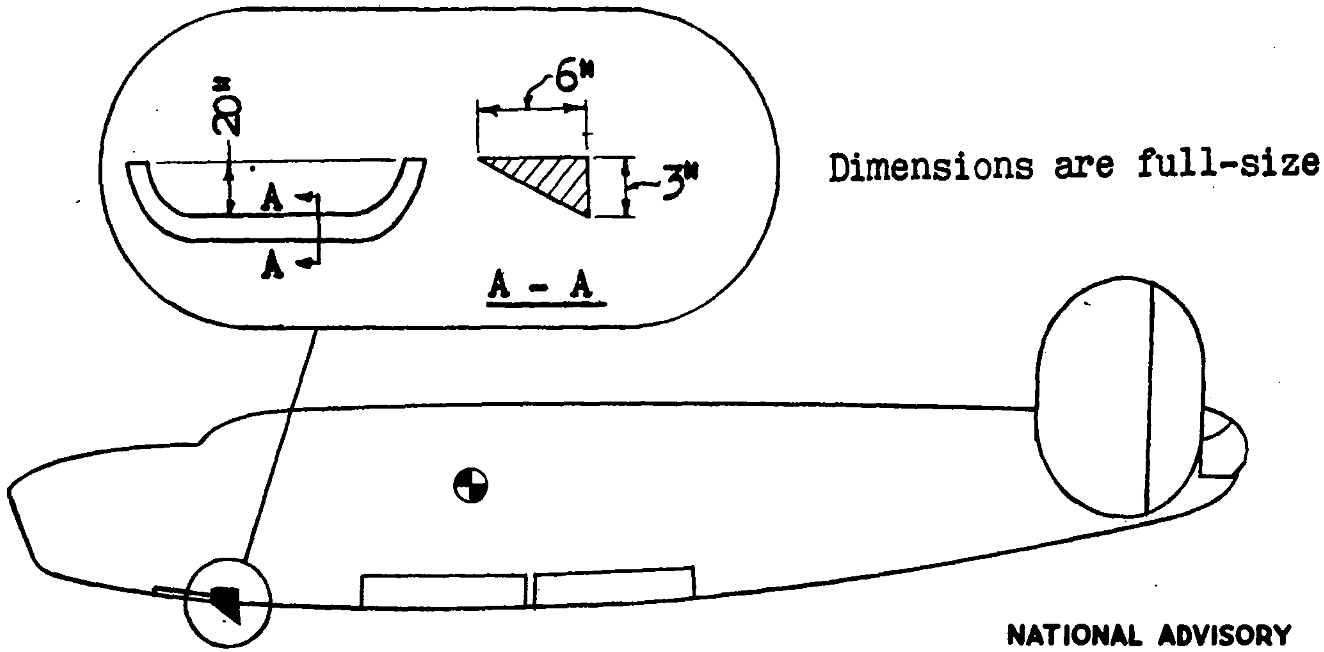

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Figure 9.- Drawing showing a triangular hydrospoiler and its location on a model of an Army B-24 airplane.

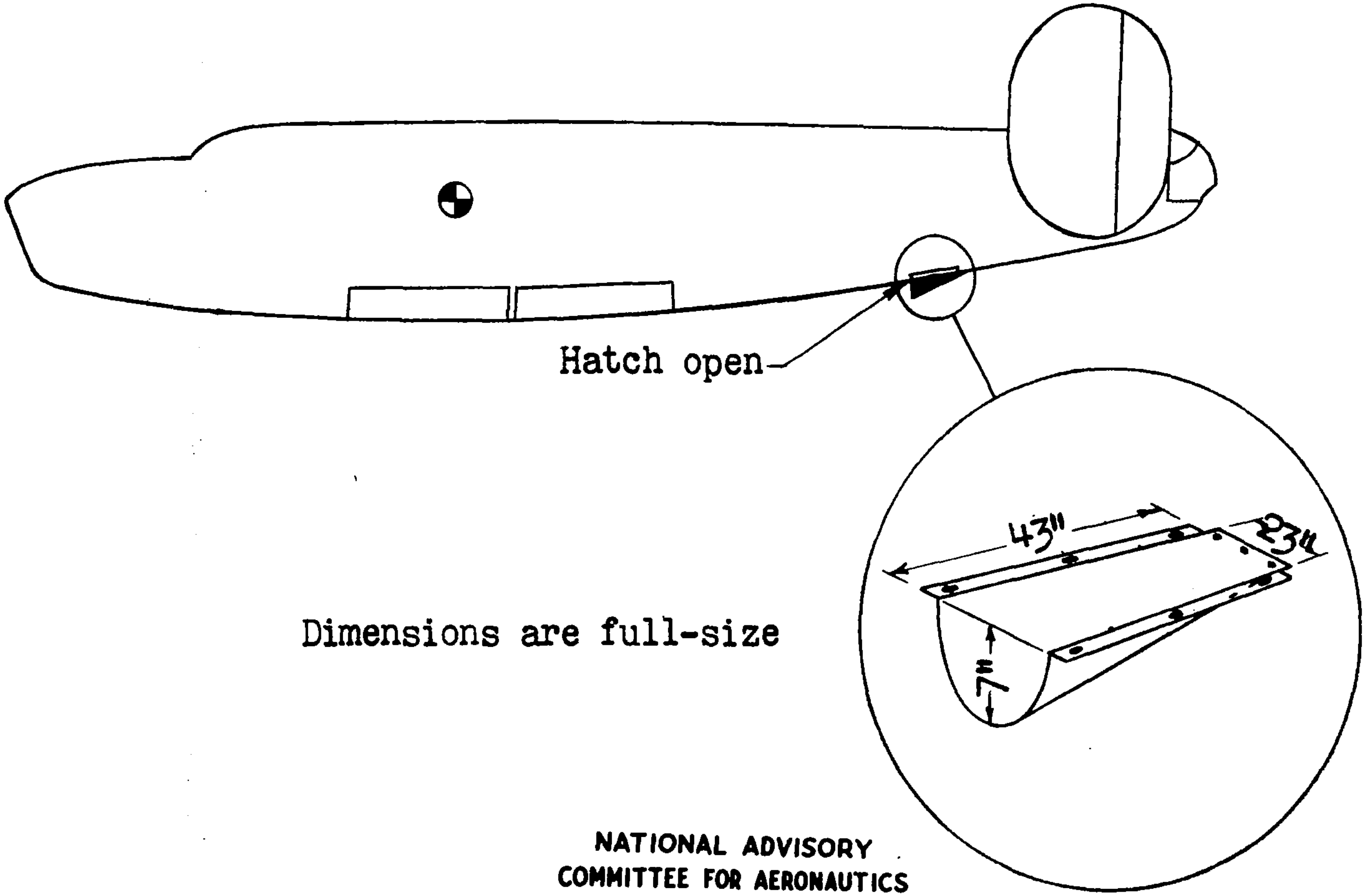

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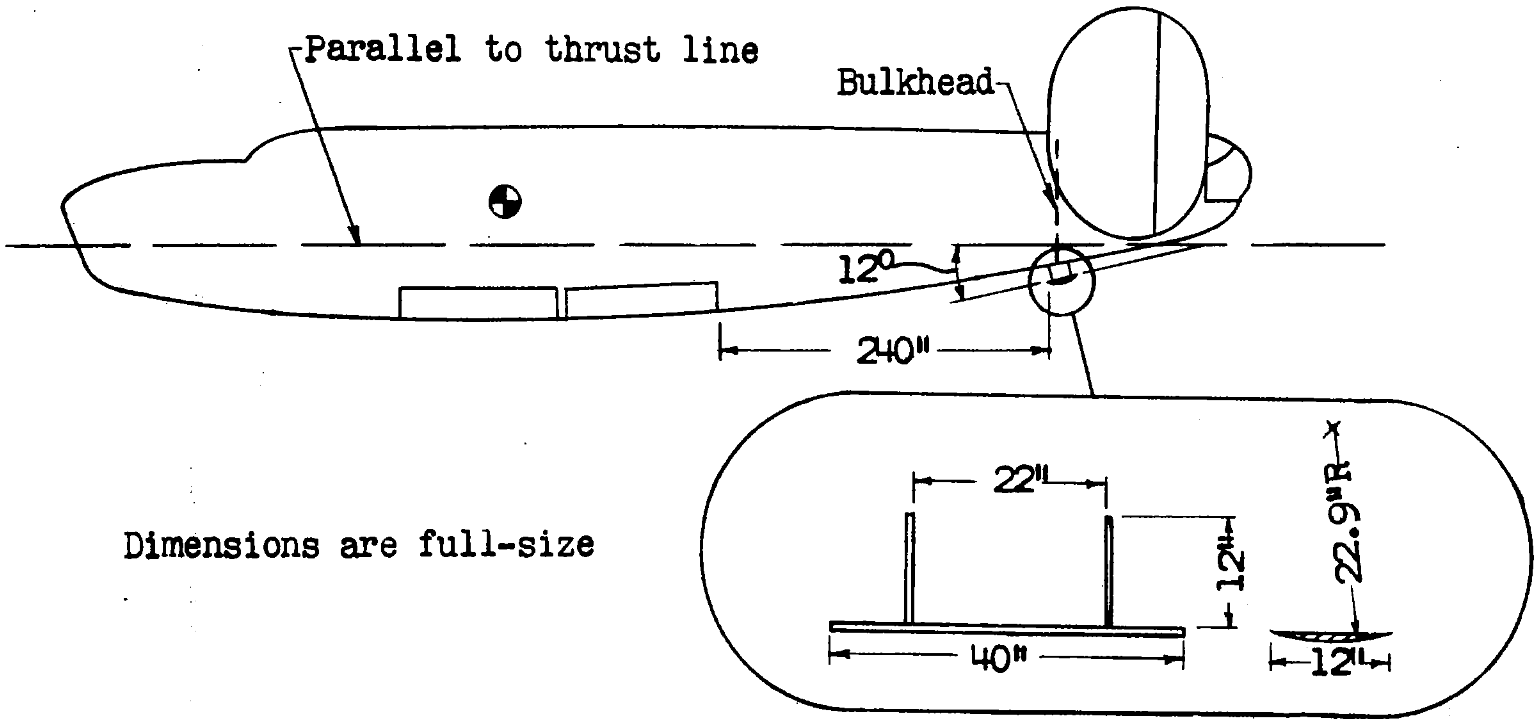
Figure 10- Drawing showing a water scoop and its location on a model of an Army B-24 airplane.



(a) 40-inch hydrofoil.

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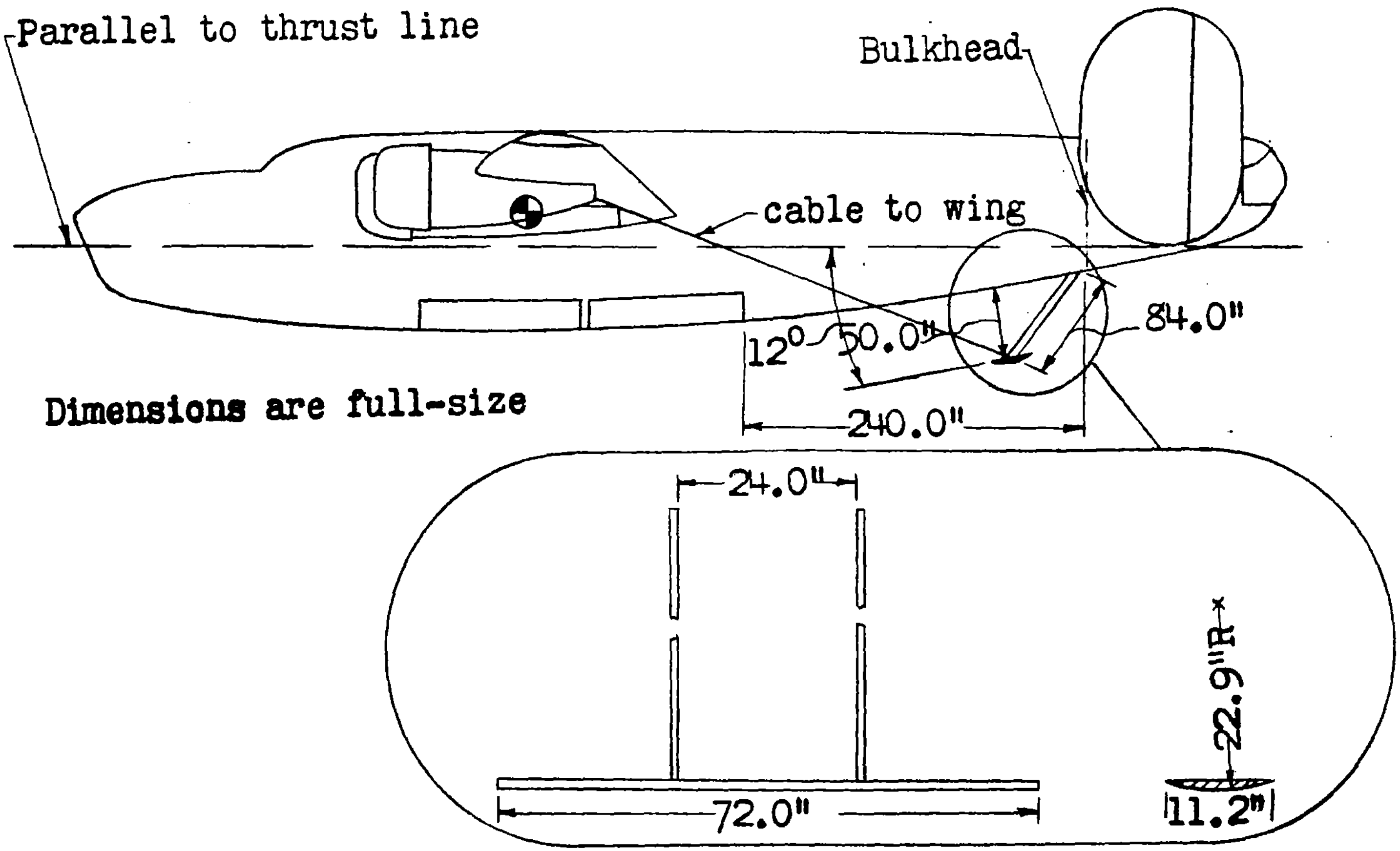
Figure 11.- Drawing showing a hydrofoil and its location on a model of an Army B-24 airplane.



Dimensions are full-size

(b) 72-inch hydrofoil.

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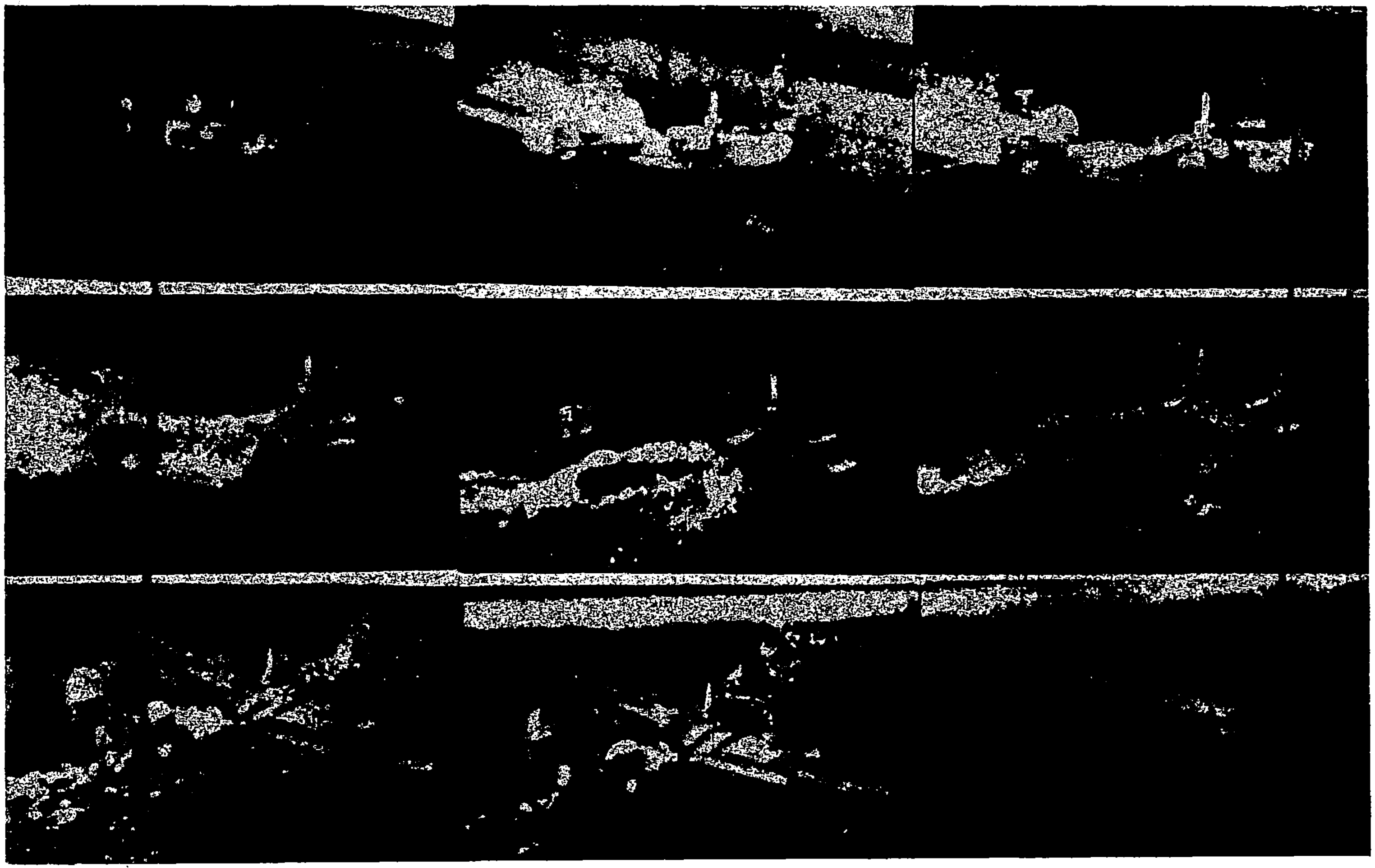
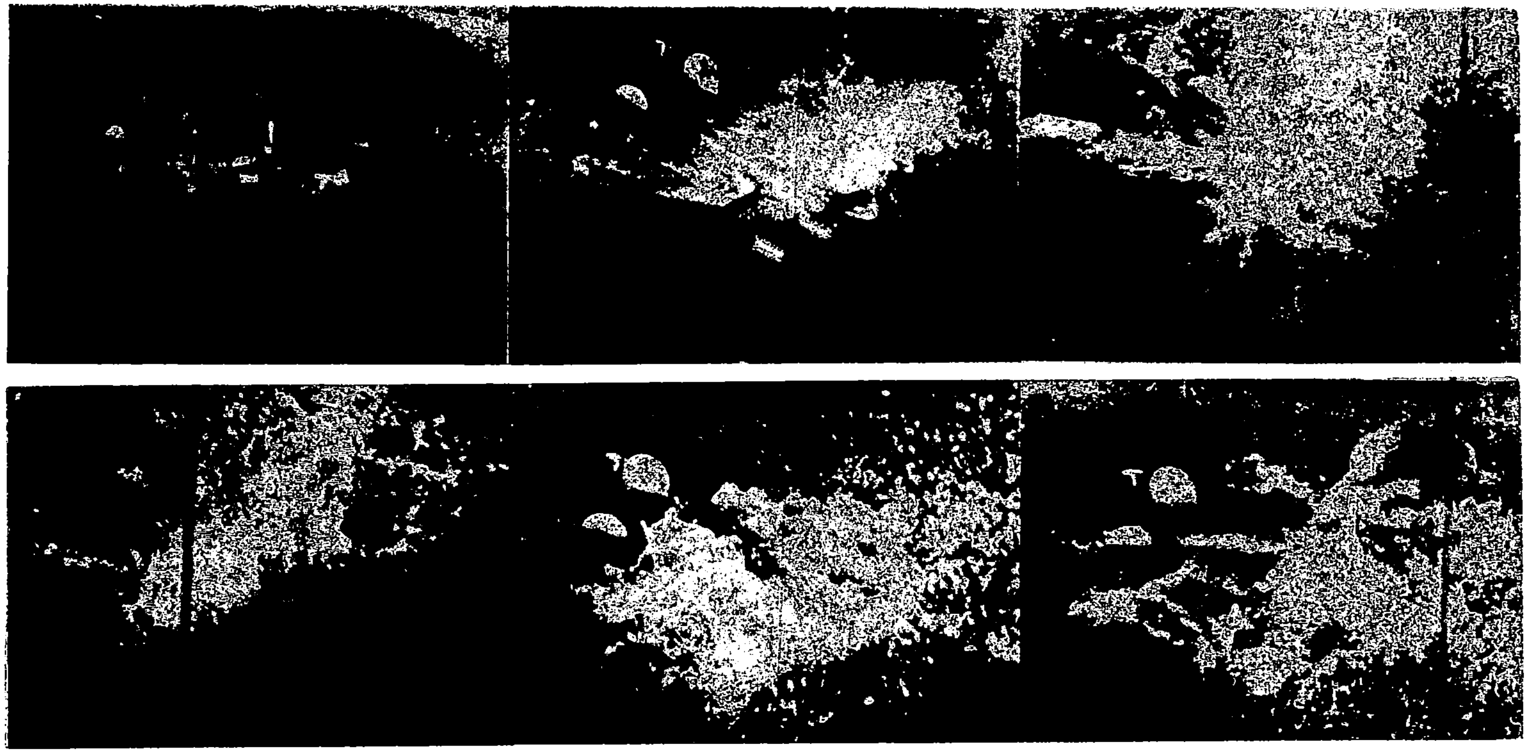
Figure 11- Concluded.



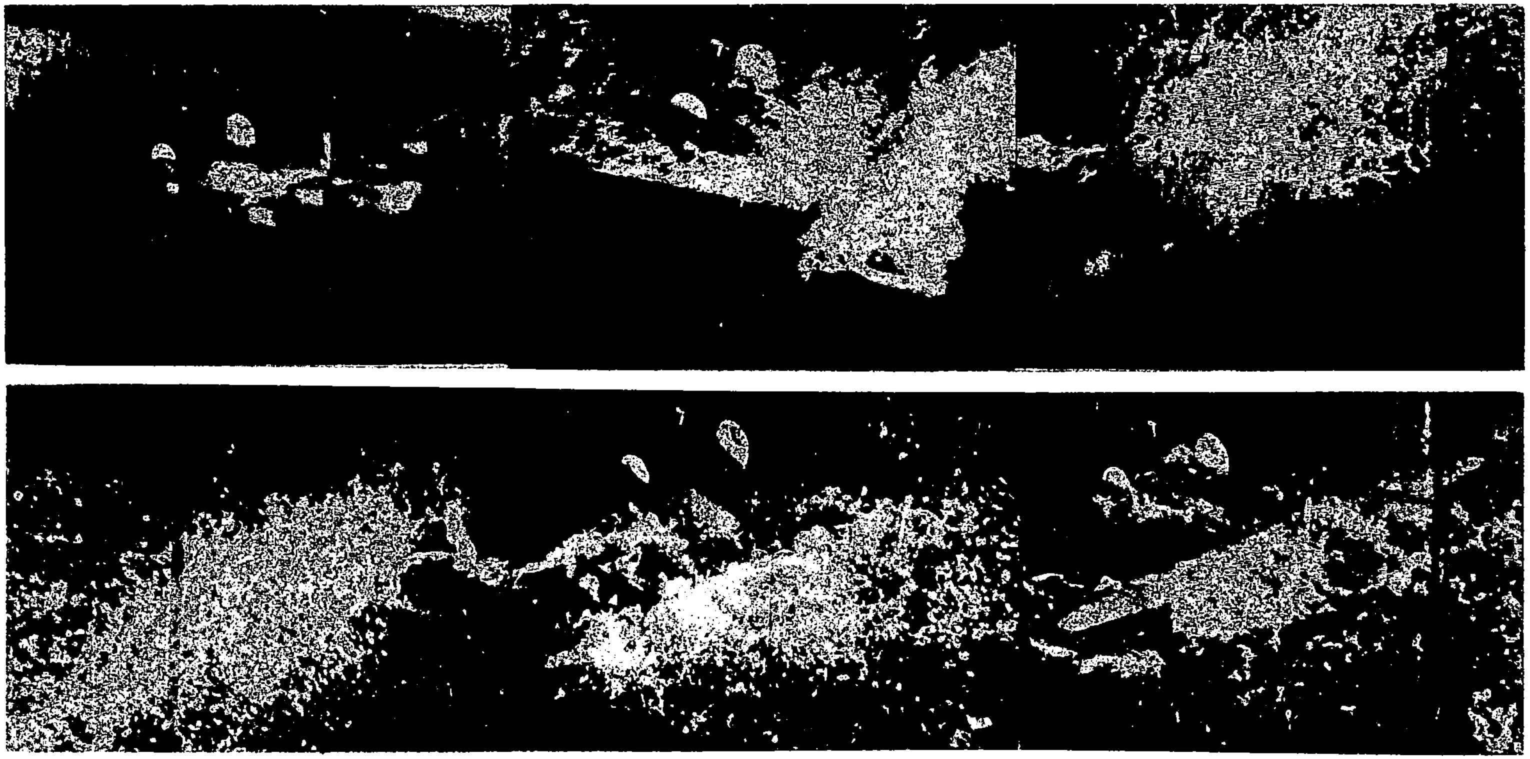
(a) Undamaged.

Figure 12.- Photographs at 1-second intervals, full-scale, of a ditching of a $\frac{1}{16}$-size model of an Army B-24 airplane. Attitude of thrust line is 9° at contact; flaps down 40°; speed 100 miles per hour, full-scale.



(b) Model with bomb-bay doors removed.

Figure 12.- Continued.



(c) Model with nose window, nose-wheel doors, bomb-bay doors, belly-turret hole, and bottom rear entrance hatch removed.

Figure 12.- Concluded.

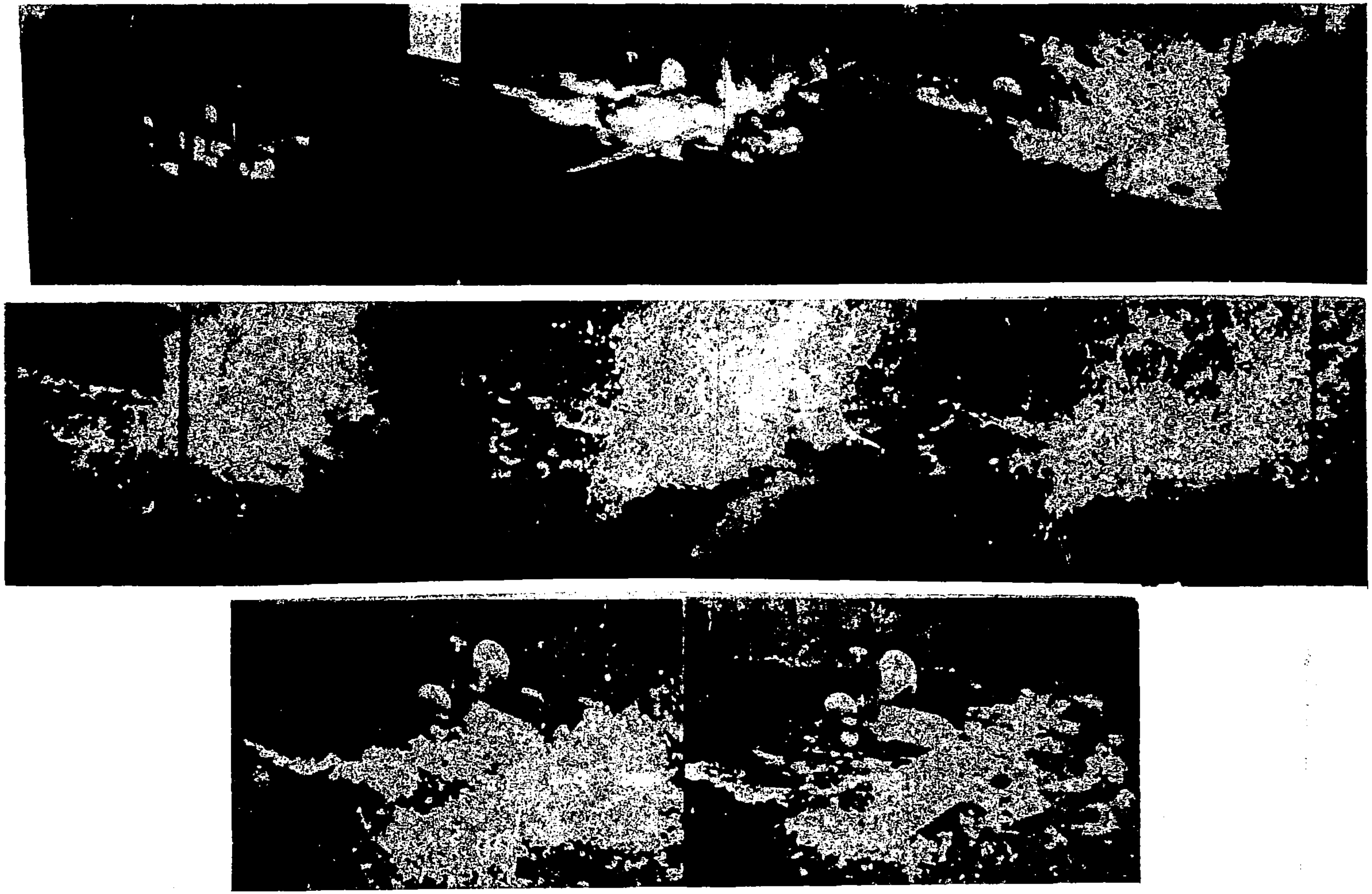


Figure 13.- Photographs at 1-second intervals, full-scale, of a ditching of a $\frac{1}{16}$-size model of an Army B-24 airplane. Attitude of thrust line is 1° at contact; flaps down 40°; speed 120 miles per hour, full-scale. Model with bomb-bay doors removed.

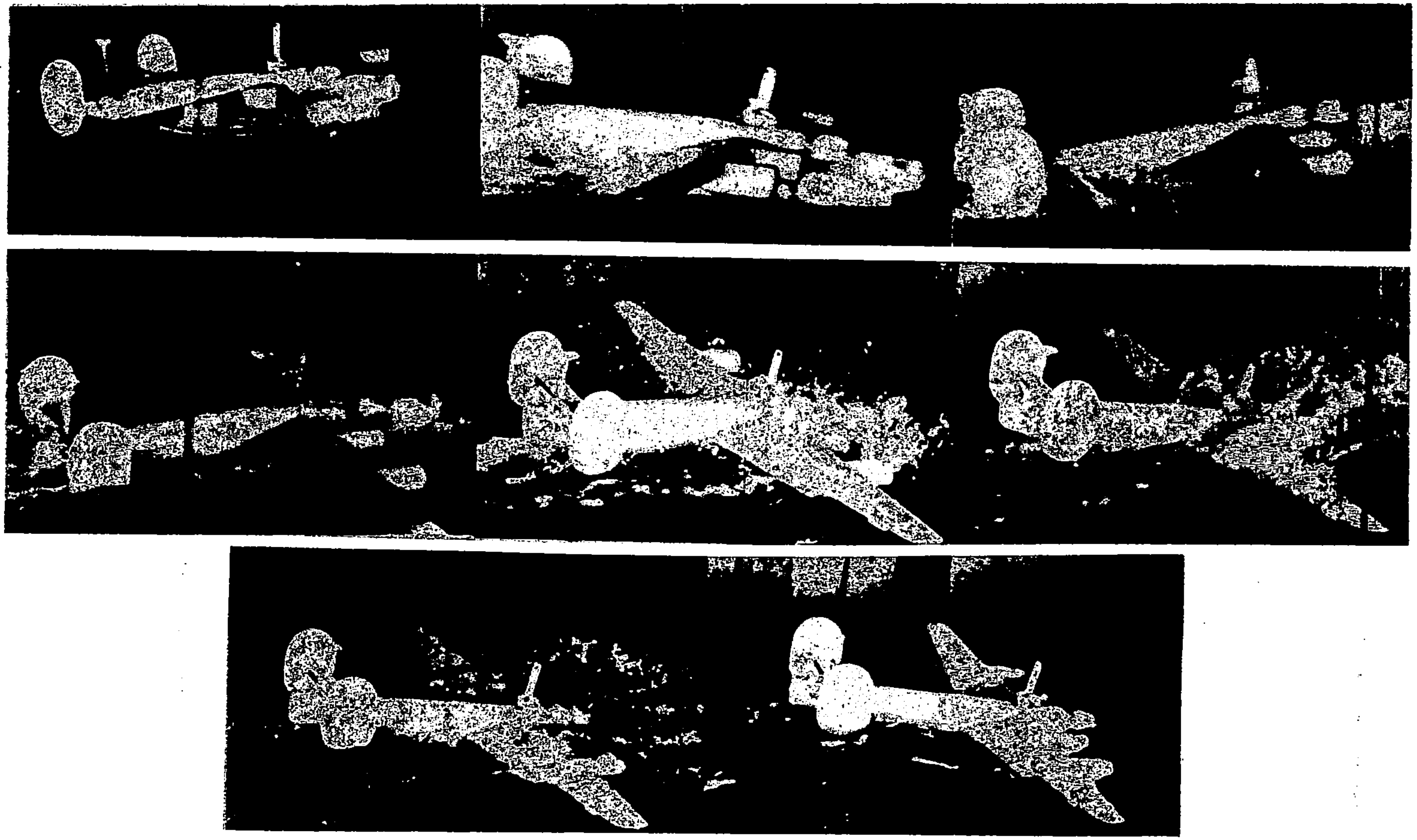


Figure 14.- Photographs at 1-second intervals, full-scale, of a ditching of a $\frac{1}{16}$-size model of an Army B-24 airplane. Attitude of thrust line is 9° at contact; flaps down 40°; speed 100 miles per hour, full-scale. Model with hydroflap attached near nose-wheel doors. Nose window, nose-wheel doors, bomb-bay doors, belly turret, and rear entrance hatch removed.

0 .37 .90 1.35 2.50 4.73

Time in seconds

Attitude (thrust line) 9°, airspeed 92 mph, weight 44,000 lb.

0 .50 .80 1.38 2.50 4.38

Time in seconds

Attitude (thrust line) 9°, airspeed 96 mph, weight 48,500 lb.

0 .50 .72 .87 1.80 4.72

Time in seconds

Attitude (thrust line) 9°, airspeed 96 mph, weight 48,500 lb.

Figure 15.- Photographs of a $\frac{1}{16}$-size model of the Army B-24 airplane ditched parallel to the waves. Nose window, nose-wheel doors, and bomb-bay doors removed.

All values are full scale

0 .80 1.38 2.10 2.50 6.22

Time in seconds

Attitude (thrust line) 1°, airspeed 125 mph.

0 .30 .43 1.05 1.80 4.42

Time in seconds

Attitude (thrust line) 1°, airspeed 125 mph.

Figure 16.- Photographs of a $\frac{1}{16}$-size model of the Army B-24 airplane ditched parallel to waves. Weight, 44,000 pounds. Nose window, nose-wheel doors, and bomb-bay doors removed.

All values are full scale

2.05 1.18 0

5.85 4.68 3.68

Time in seconds

Attitude (thrust line) 9°, airspeed 92 mph.

.75 .25 0

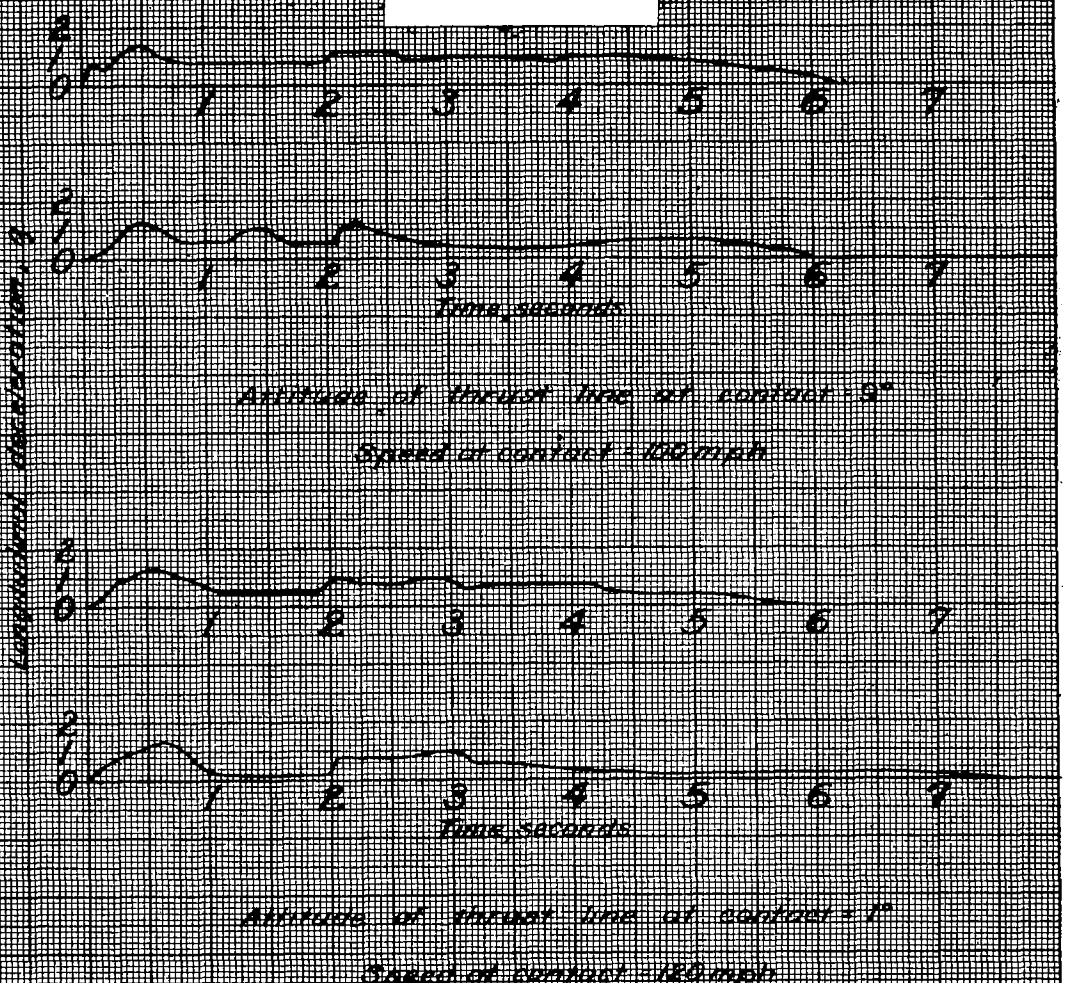
4.55 2.25 1.30

Time in seconds

Attitude (thrust line) 5°, airspeed 108 mph.

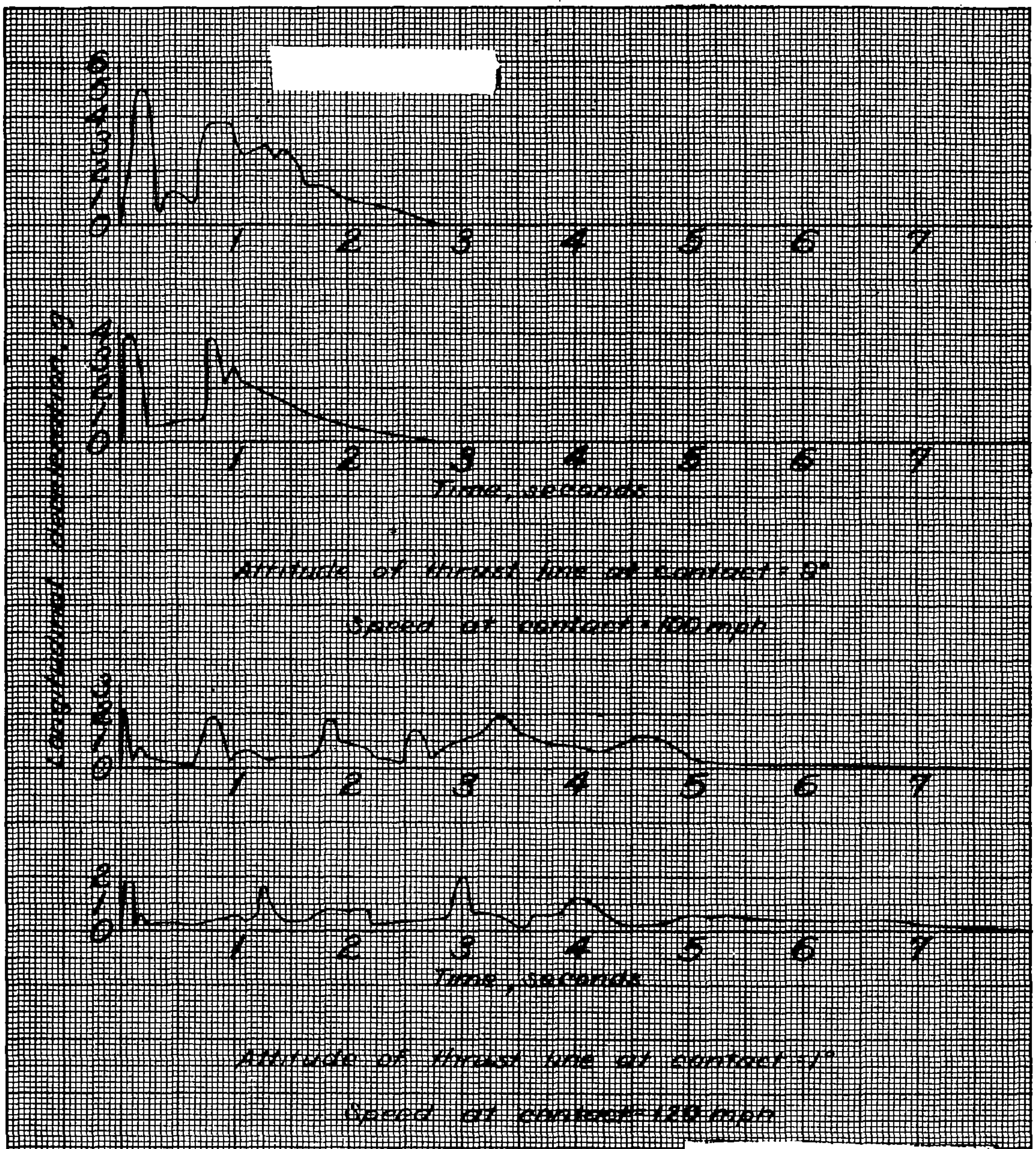
Figure 17.- Photographs of a $\frac{1}{16}$-size model of the Army B-24 airplane ditched across the waves. Weight, 44,000 pounds. Nose window, nose-wheel doors, and bomb-bay doors removed.

All values are full scale



(a) Undamaged

Figure 18 - Time histories of longitudinal decelerations for ditchings in calm water of a [illegible] size model of an Army B-24 airplane. Flaps down 40°. All values are full scale.



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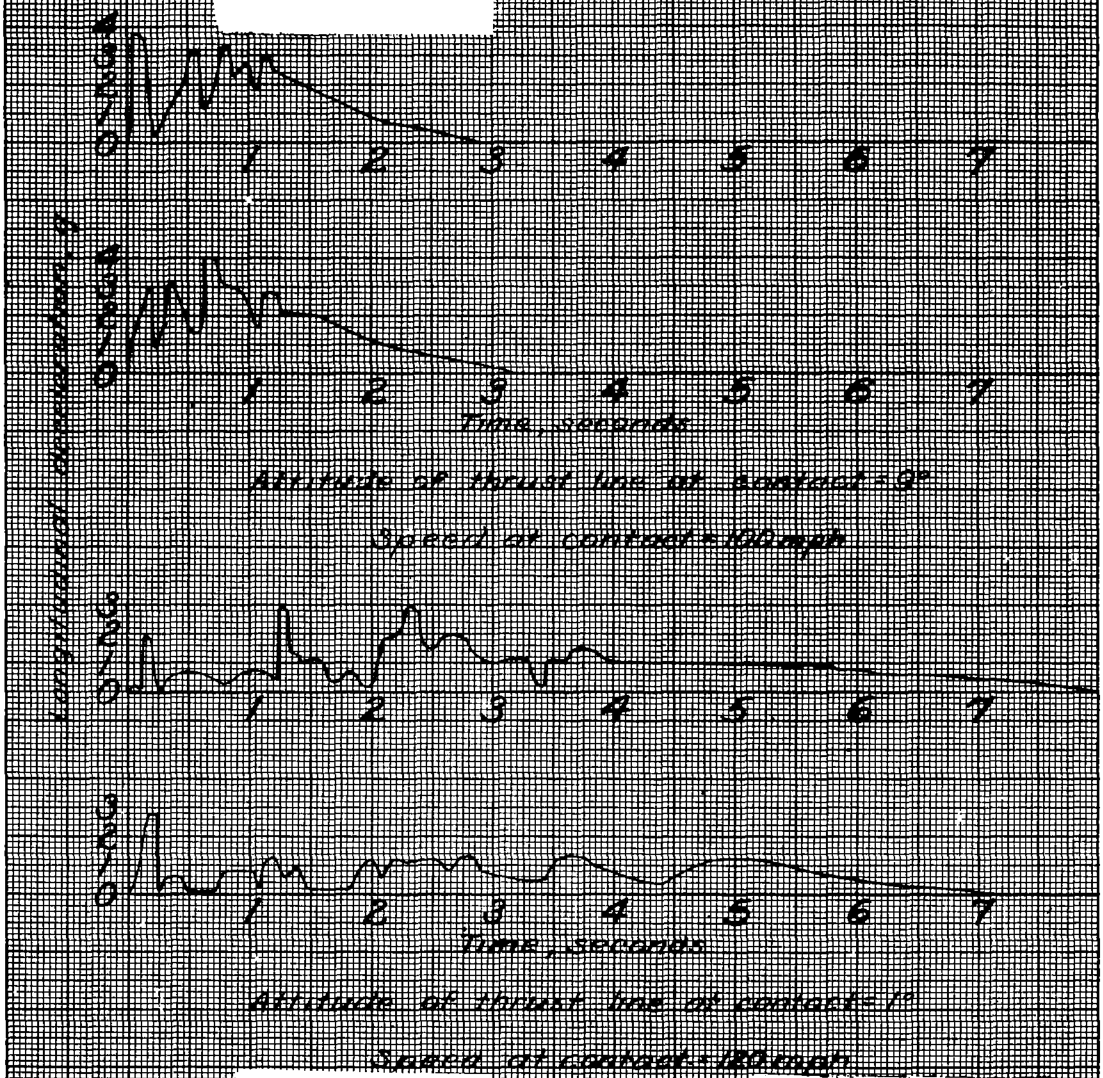
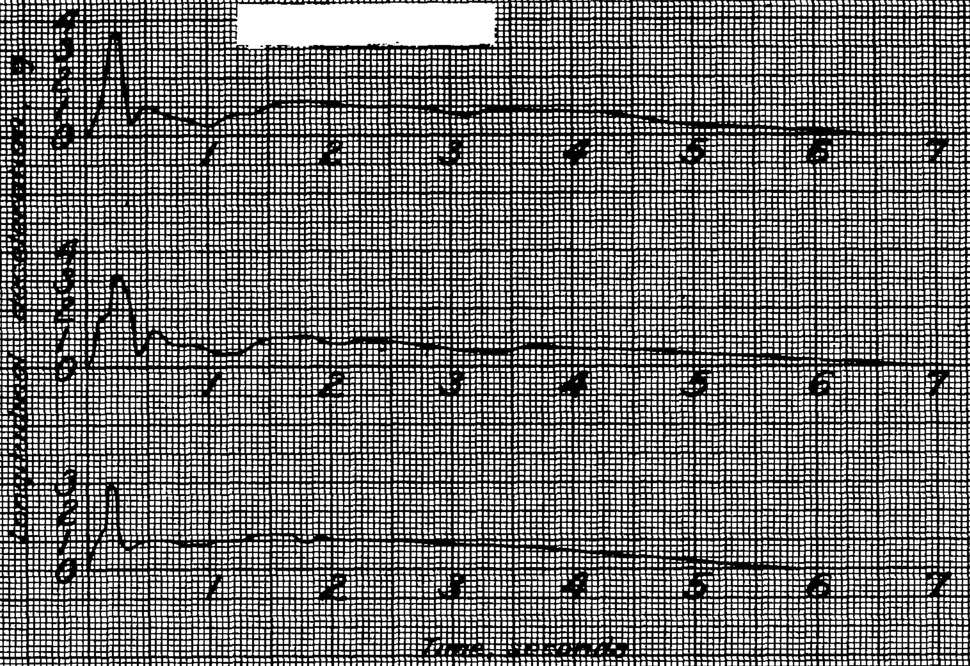
(b) Bomb-bay doors removed

Figure 18.- Continued.



(c) Nose window, nose-wheel doors, bomb-bay doors, belly turret & rear entrance hatch removed

Figure 18 - Concluded.



Attitude of thrust line at contact = 9°

Speed at contact = 100 mph

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Figure 10.- Time histories of longitudinal decelerations for ditchings in calm water of a 1/16-size model of an Army B-24 airplane. Model with hydroflap attached near nose-wheel doors. Nose window, nose-wheel doors, bomb-bay doors, belly turret and rear entrance hatch removed.
Flaps down 40°.
All values are full-scale.